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The Seventieth Meeting of the American Astronomical Society

By DEAN B. McLAUGHLIN

It was some three years ago that Dr. Harlow Shapley invited the American Astronomical Society to hold its summer meeting of 1943 at the Harvard College Observatory, in conjunction with a proposed celebration of the centennial of that institution. But by the time 1943 had rolled around, it was even a little doubtful whether meetings would be held at all, and the Council left arrangements in the hands of the President and Secretary. When President Stebbins took up the subject with Dr. Shapley, it was learned that the centennial celebration had been called off. Doubtless the Director of the Harvard Observatory wanted to have the celebration when his staff could be on hand to take part! The holding of a Society meeting, however, was a different matter, and we were assured we would be welcome.

What with the changes of college schedules on account of the war, no date that could have been chosen would have been completely satisfactory. The week-end May 28-30 was fixed on by correspondence between the President, Secretary, and Dr. Shapley.

Any meeting at Harvard is likely to be well attended, even in war time. A considerable astronomical population resides within a short journey of Cambridge, and the loss of astronomers from the observatory has meant, in some cases, that they are working at the Harvard or M. I. T. laboratories, and can be counted on to help furnish a quorum. Those who have left Cambridge have been partly compensated for by an influx of astronomers from outside to the Radiation Laboratory at M. I. T.

The record shows that 72 members and 24 guests were present, and it is believed that several guests were not recorded in the register. Not many came from long distances. Dr. McKellar travelled all the way from Victoria, the President and Secretary came from Wisconsin and Michigan, respectively, Dr. and Mrs. Nassau came from Cleveland, Mrs. Hogg from Toronto, and Dr. Burns from Pittsburgh. The rest "also ran." Travelling conditions were discouraging to long journeys. The Secretary succeeded in getting a lower berth by making his reservation three weeks in advance.

Many of the visiting astronomers stayed at the Commander Hotel. The Continental Hotel was already fully booked up when the Secretary made inquiries a month before the meeting. Owing to the Harvard and

Radcliffe commencements, Cambridge was particularly crowded with outsiders, and lodgings were at a premium, but all the astronomers were taken care of one way or another, and none had to make use of a bench on the Common.

The Council held a meeting at the Commander Hotel at 5 P.M. Friday, starting in the lounge and finishing in the dining room, thus following the precedent established at Evanston. The business was mostly routine, and that which was not will be released elsewhere.

The first general session was that of the Teachers' Conference, which was held in the library-auditorium of building D at 8 P.M. Dr. Joel Stebbins spoke on "Copernicus and Modern Revolutions" as the Society's recognition of the quadricentennial of the publication of "De Revolutionibus Orbium Coelestium." During the preceding few weeks he had given addresses on at least three occasions on the subject of Copernicus, of lengths varying all the way from five minutes to an hour. Now, with one of about thirty minutes for the Society, he was ready to call it quits. The second speaker was Dr. Charles H. Smiley, who spoke on "Emergency Navigation with Limited Equipment," or how to tell where you are and go where you want to (assuming you have some motive power), without the customary aids and instruments of the navigator,—in short, with nothing but a watch. The interest in the subject was evident from the length of discussion which followed, during which Dr. Bok contributed some ideas which he has been presenting in courses at Harvard.

After the conclusion of the discussion, Dr. and Mrs. Shapley held a reception for the Society at the observatory residence, and refreshments were served, including (believe it or not) coffee. This was the time for much handshaking and talking,—shop and otherwise,—until a moderately late hour. Then the guests departed by twos and threes, to find their way to hotel or lodging house through the dimout, which was quite reminiscent of New Haven a year ago. It is no trick at all to see fifth magnitude stars from the Harvard Observatory, or even fourth magnitude from Harvard Square!

On Saturday morning a session for papers was held at the observatory, and the group photograph was taken at noon. If the people in the back row look somewhat apprehensive, it is because they were perched precariously on folding chairs.

In the afternoon the annual business meeting was held. First came the election of officers, with the following results:

President	1943-46	Harlow Shapley
Vice-President	1943-45	Robert R. McMath
Secretary	1943-44	Dean B. McLaughlin
Treasurer	1943-44	Keivin Burns
Councilors	1943-46	Harold D. Babcock
		Dirk Brouwer
		J. J. Nassau

Member of Division of
Physical Sciences,
Nat. Res. Council, 1944-47 E. P. Hubble.

Except for the Councilors and the member of the Division of Physical Sciences, the outcome would have been a sure bet, since there was only one candidate for each office. One member (whom we shall not name) asked the Secretary if that was his idea of democracy.

Next, following nominations from the floor, a nominating committee was elected as follows:

Paul W. Merrill, *Chairman*
Charlotte Moore Sitterly
A. E. Whitford.

It will be the duty of this committee to prepare the slate of candidates for the next election, in the summer of 1944. If you have any friends whom you would like to see holding office, just write to one or all three of these committeemen. If you can unearth a candidate for Secretary, besides the present incumbent, the latter will be grateful, and if you can manage a successful campaign for the opponent, you will be treated to the best dinner in town.

The Treasurer reported the Society's finances in good condition, and stated that a number of people who had been in arrears on their dues had paid up. Apparently this is the first time in years when some of them have had enough money to pay their dues!

Following the business meeting there was a second session for papers, which completed the program. In all, 21 papers were presented. Though far below normal as to quantity, the quality seems not to have suffered and may even have improved. Indeed, there is something to be said for short programs; the saturation point of the average listener is less likely to be reached or passed. A couple of years ago, after an especially long meeting with many papers, a group of astronomers was engaged in small-talk when one of them mentioned some technical point concerning one of the papers. The attempt to talk shop was neatly nipped in the bud when another of the group remarked: "I'm allergic to astronomy."

The Society dinner was held that evening, at the Harvard Faculty Club. More than one hundred were present, though the pre-meeting estimate had been fifty, and the number of reservations only eighty. Miraculously, in spite of rationing and shortages, there was food for all, though the menu was far from homogeneous. "What did you have?" was a standard question that was heard afterwards.

After the dinner, Miss Mary Collins of the department of geology of Harvard University gave an illustrated talk on earthquakes and volcanoes, including the recent nova among volcanoes, Paracutin in Mexico. Dr. Joel Stebbins showed Kodachrome slides of his trip to

Mexico in 1942 (at the time of the dedication at Tonanzintla). He then passed the gavel, as the symbol of office, to Dr. Shapley, the newly elected President, with some appropriate remarks.

Dr. Shapley invited the Society to meet again at Harvard, after the war, to celebrate the centennial of some phase of the early development of the Harvard Observatory. Some historical research had revealed the fact that any year up to 1950 will be entirely valid, since something worth celebrating happened just a century earlier.

This concluded the meeting, so far as most members were concerned. On Sunday morning the Council, including its new members, held a long session in the lounge of the Commander Hotel. Special problems, including some concerned with publications, were considered. They adjourned about noon, and most of them left Cambridge soon after. The Secretary, however, stayed on for a few days to combine business with pleasure, write letters concerning the meeting, examine Harvard spectra of novae, and, as the retiring President remarked, get the new President started working for him!

The sequel was as much a surprise to the author as to anybody, though there was considerable basis for premonition at the time of the meeting. A few days of vacation were spent working out a few remaining details of a favorite geologic section along the Delaware River, and to pondering an important question. Then followed the return to Ann Arbor for a few days to "wind up affairs," and the trip east again, to become a member of the staff of the Radiation Laboratory at M. I. T. Until further notice, then, the office of the Secretary will be at the Harvard Observatory, and he will sandwich the work of the Society in between matters of a more deadly significance.

CAMBRIDGE, MASSACHUSETTS, JULY 10, 1943.

Report of the Conference of Teachers of Astronomy at Cambridge, Massachusetts

By MARJORIE WILLIAMS

The conference of Teachers of Astronomy was held at the Harvard College Observatory at eight o'clock on the evening of May 28, 1943. Dr. Alice H. Farnsworth, chairman of the Teachers Committee, presided, and introduced as the first speaker Dr. Joel Stebbins, president of the American Astronomical Society, who took as his subject "Copernicus and Modern Revolutions." He spoke of 1543, the year of the death of Copernicus and of the publication of his book "De Revolutionibus Orbium Coelestium," as the zero epoch among the many centennials we celebrate. The name of Copernicus stands out at the discontinuity be-

tween the old and the new astronomy. This talk is printed in full in the June issue of POPULAR ASTRONOMY.

At the conclusion of Dr. Stebbins' talk a brief business session was held. Reporting on the personnel of the Teachers Committee, Miss Farnsworth announced that Dr. Smiley had been asked to fill a vacancy on the committee for the past year. In accordance with the plan of perpetuation of the committee formulated at the New Haven meeting[1] two members were due to retire this year. These were chosen by lot at a meeting of the committee held at the Hotel Commander on the afternoon of May 28. All members were present except Dr. Wylie. The two who retire are Dr. Farnsworth and Dr. Wylie. We gratefully acknowledge the debt the committee owes these two members, and it is with regret that we see them retired from service. The committee placed in nomination for the vacancies the names of Miss Leah B. Allen, Mr. Earl Linsley, and Mr. N. Wyman Storer. Nominations from the floor were called for, and Mrs. Helen Hogg was suggested. A vote by ballot was taken, and Miss Allen and Mrs. Hogg were elected, making the present committee consist of Dr. J. J. Nassau, Miss Leah B. Allen, Mrs. Helen S. Hogg, Miss Marjorie Williams, and Dr. Charles H. Smiley, chairman.

Miss Farnsworth reported that reprints of the report of the Committee on Preferred Spellings and Pronunciations had been distributed to about 150 individuals and societies. The response to the accompanying request for donations was sufficient to cover expenses of printing the report and the reprints. A convenient list of the constellations with three and four letter abbreviations, already sent to donors, is available.

The second speaker was Dr. Charles H. Smiley of Brown University, who spoke on "Emergency Navigation with Limited Equipment." For a person adrift in a life-boat a watch is the minimum navigational requirement. With a watch and tables of the lengths of day on various dates in different latitudes and the values of the equation of time, it is possible to find the latitude and longitude. With a map of the Earth, a star map, and a list of times when certain stars pass through the zeniths of selected ports around the world, one is able to find out which way to set his course to reach land. Dr. Smiley has written up his method in two articles in POPULAR ASTRONOMY, March, 1943, p. 136, and May, 1943, p. 245. This talk brought forth considerable discussion, and other emergency methods were described by Dr. Bart J. Bok and others.

SMITH COLLEGE OBSERVATORY, NORTHAMPTON, MASSACHUSETTS.

[1] POPULAR ASTRONOMY, August, 1942, p. 354.

The Four Penumbral Lunar Eclipses of 1944

By ALEXANDER POGO

In the year 1944, there will be six eclipses—two of the Sun and four of the Moon. During the January-February eclipse season of 1944, there will be two eclipses; the total solar eclipse of January 25 will be followed by the penumbral lunar eclipse of February 9. During the July-August eclipse season of 1944, there will be three eclipses; the annular eclipse of the Sun of July 20 will be preceded by the penumbral lunar eclipse of July 6 and will be followed by the penumbral lunar eclipse of August 4. The winter eclipse season of 1944-45 begins with the penumbral lunar eclipse of 1944 December 29. Thus, there will be six eclipses in 1944. Incidentally, the Julian calendar year 1944 barely misses being a year with seven eclipses—the annular eclipse of 1945 January 14 (Gregorian) begins a few hours after the end of the Julian calendar year 1944.

The circumstances of the four penumbral lunar eclipses of 1944 are given in Table I; see also Figures 1 to 4. The negative magnitudes measure, in fractions of the lunar diameter, the gap between the Moon's limb and the physical umbra.

TABLE I

THE PENUMBRAL LUNAR ECLIPSES OF 1944

	February 9	July 6	August 4	December 29
	h m	h m	h m	h m
Moon enters penumbra.....	3 18 U.T.	3 0 U.T.	10 53 U.T.	12 33 U.T.
Middle of the eclipse.....	5 15	4 39	12 26	14 49
Moon leaves penumbra.....	7 12	6 18	13 59	17 5
Magnitude of the eclipse....	−0.51	−0.43	−0.47	−0.01
Approach to physical umbra.	15′1	13′8	15′5	0′3
Moon in the zenith at mid-eclipse: Longitude	75°W	70°W	175°E	139°E
Moon in the zenith at mid-eclipse: Latitude	16°N	21°S	18°S	22°N

The penumbral lunar eclipse of 1944 February 9—in the zenith over the Caribbean Sea—will be beyond the reach of the unaided eye, but it could be observed photographically. As seen from the southern half of the Moon, the large and atmosphere-fringed terrestrial disk will encroach on the southern limb of the Sun. On February 9, 1944, the Sun will be partially eclipsed, as seen from Tycho, within the penumbral cone of the Earth, just as the Sun was partially eclipsed, on March 16, 1942, as seen from the Bellingshausen Sea, within the penumbral cone of the Moon; in both cases, the southern part of the Sun is hidden by the intervening disk. Enough direct sunlight reached the eclipsed regions of the South Pacific Ocean and of Antarctica, during the *eclipsis telluris* of March 16-17, 1942, to make the darkening of the Earth's surface imperceptible to a hypothetical observer located on the Moon; enough

direct sunlight will reach the eclipsed regions of the Moon, on February 9, 1944, to make the darkening of the Moon's surface imperceptible to the unaided eye of an observer located on the Earth; in both cases, the northern part of the Sun provides the direct illumination of the eclipsed regions. To an unprejudiced student of the Sun-Earth-Moon eclipse mechanism, the immersion of the southern part of the Moon, on Febru-

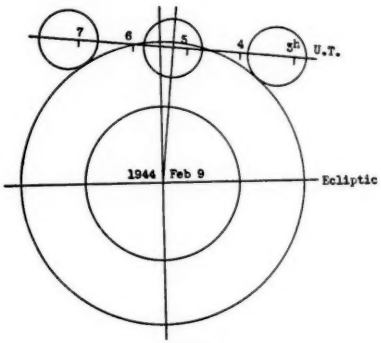

FIGURE 1
The Penumbral Lunar Eclipse of
1944 February 9

ary 9, 1944, into the northern outer layers of the penumbral cone attached to the Earth, is a celestial phenomenon analogous to the immersion of the southern part of the Earth, on March 16-17, 1942, into the northern outer layers of the penumbral cone attached to the Moon; in both cases, we have a penumbral eclipse; in both cases, the Sun is partially eclipsed, as seen from the darkened regions; in both cases, there is no change in the appearance of the darkened regions, as seen from the eclipsing body.

The penumbral lunar eclipse of 1944 July 6—in the zenith over northern Chile—will be well within the reach of the photographic camera, although it will remain unobservable to the unaided eye. As seen from the southern half of the Moon, the disk of the Earth will encroach on the southern limb of the Sun. On July 6, 1944, the Sun will be partially eclipsed, as seen from Tycho, within the penumbral cone of the Earth, just as the Sun was partially eclipsed, on August 12, 1942, as seen from Wilkes Land, within the penumbral cone of the Moon; in both cases, the southern limb of the Sun is hidden by the intervening disk. It ought to be mentioned that the eclipse of 1942 August 12 was, from a "practical" point of view, a negligible phenomenon; at maximum phase, only 0.055 of the Sun's diameter were hidden—about 0.02 of the area of the Sun's disk; Wilkes Land and the southernmost part of the Indian Ocean are desolate places. From

a theoretical point of view, the eclipse of 1942 August 12 was an important event; it brought to a close the solar saros series S95 which

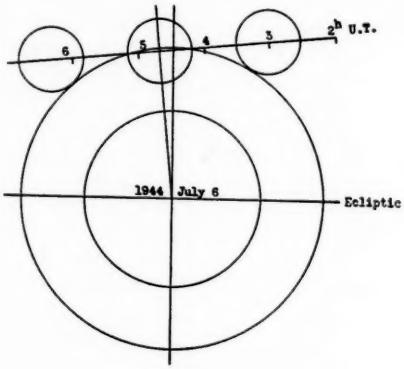

FIGURE 2
The Penumbral Lunar Eclipse of
1944 July 6

started with the arctic eclipse of 680 July 1; there were 71 eclipses in the saros series, 9 in the initial penumbral run, 55 in the umbral run, and 7 in the terminal penumbral run; S95 was a typical minor saros series (see Table IV in POPULAR ASTRONOMY, **43**, 339, 1935).

The penumbral lunar eclipse of 1944 August 4—in the zenith over the southwestern part of the Pacific Ocean, between the New Hebrides and the Fiji Islands,—will be observable photographically, but not

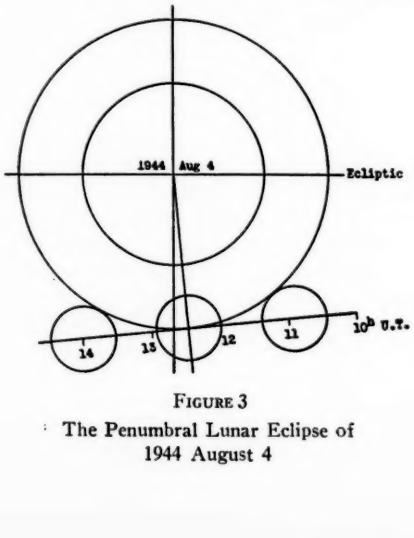

FIGURE 3
The Penumbral Lunar Eclipse of
1944 August 4

visually. As seen from the northern half of the Moon, the terrestrial disk will encroach on the northern limb of the Sun. On August 4, the Sun will be partially eclipsed, as seen from Plato, within the penumbral cone of the Earth, just as the Sun was partially eclipsed, on September 10, 1942, as seen from the Barents Sea, within the penumbral cone of the Moon; in both cases, the northern part of the Sun is hidden by the intervening disk. Enough direct sunlight reached the eclipsed regions of the Earth, on September 10, 1942, to make the darkening imperceptible to an observer located on the Moon; enough direct sunlight will reach the eclipsed regions of the Moon, on August 4, 1944, to make the darkening imperceptible to an observer located on the Earth; in both cases, the southern part of the Sun's disk provides the direct illumination of the eclipsed regions.

The penumbral lunar eclipse of 1944 December 29—in the zenith over the western part of the Pacific Ocean, between Japan and the Caroline Islands,—will be a very conspicuous phenomenon, visible to more than half the population of the Earth. At mid-eclipse, the Moon will be near the meridians of Tokyo (139°.5 E) and of Adelaide

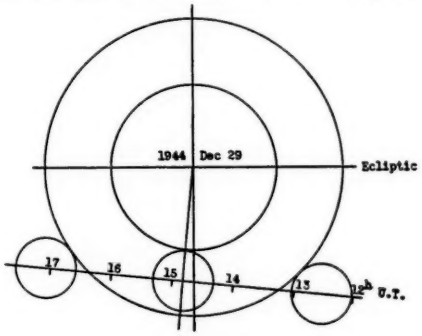

FIGURE 4
The Penumbral Lunar Eclipse of
1944 December 29

(138°.6 E). The eclipse will be visible in the arctic and northwestern parts of North America, the Pacific Ocean, Polynesia, New Zealand, Australia, the Indian Ocean, Asia, eastern and northern Europe, the Arctic Ocean, and northern Greenland. As seen from *any* point on the Moon facing the Earth, the Sun will be partially eclipsed; an observer located near the southern limb of the Moon would see a slight encroachment of the terrestrial disk on the northern limb of the Sun; near the northern limb of the Moon, practically all direct sunlight will be cut off, only a narrow portion of the southern limb of the Sun remaining visible. As seen from the Earth, the northern limb of the Moon will pass through the dark inner layers of the penumbra; at maximum phase,

the darkened northern limb of the Moon will look flat; the flattened northern limb of the Moon will be the *lower* limb for observers located on New Guinea and in Australia; to them, the eclipsed Moon will look like a flat tire, on the night from Friday, December 29, to Saturday, December 30, 1944.

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Approximate Determination of Astronomical Refraction

By NELSON B. CONKWRIGHT

In this discussion the letter h is used to represent the observed altitude of a celestial body, and r denotes the mean astronomical refraction which is applied as a correction to the apparent altitude. It is well known that the approximate value of r can be computed by means of Comstock's formula, which has long been familiar to workers in astronomy. Because of the general interest in navigation at the present time, it seems desirable to point out that this formula can be somewhat simplified and still yield results accurate enough for the purpose of the practical navigator.

It has apparently not been observed (at least by the authors of manuals on navigation) that the refraction can be obtained with a rather satisfactory degree of accuracy merely by taking r (in minutes of arc) to be cot h. If h is not less than 20°, the error in the value of r as thus found is never greater than 0′.1, and in most instances is considerably less than this. The error decreases rapidly as h increases, being about 0′.03 when $h = 50°$. An accuracy to the nearest tenth of a minute of arc is quite sufficient for practical navigation. For bodies less than 20° above the horizon, the error is somewhat greater, being about 0′.35 when $h = 10°$.

A much better value of the mean refraction can be obtained by taking

$$r = \cot h - (1/30) \cot h. \tag{1}$$

When $h \geqslant 20°$, this formula gives r with an error not greater than 0′.01. The value of r as given by (1) is slightly less accurate when $h < 20°$, being in error by 0′.16 when $h = 10°$.

Thus r can be found quickly and easily when a slide rule or table of cotangents is available.

The preceding remarks can be partially verified by an examination of the following tabulation. The entries in the table are rounded off to the nearest figure in the second decimal place. To reveal the actual error resulting from the use of (1), it would be necessary to have the quantities in the table expressed to three or more decimal places.

h	r	cot h	cot h — (1/30) cot h
10°	5′.32	5.67	5.48
20°	2′.65	2.75	2.66
30°	1′.68	1.73	1.67
40°	1′.16	1.19	1.15
50°	0′.81	0.84	0.81
60°	0′.56	0.58	0.56
70°	0′.35	0.36	0.35
80°	0′.17	0.18	0.17

To understand the origin of the approximations to r which have been described, it is necessary to examine Comstock's formula. It is

$$s = (983\, b \tan z)/(460 + t), \tag{2}$$

where s is the refraction in seconds of arc, b is the barometric pressure in inches of mercury, t is the temperature (Fahrenheit), and z is the apparent zenith distance of the celestial body observed. The mean refraction as given by Comstock's formula is obtained by substituting $b = 30$, $t = 50$. Formula (2) then becomes

$$s = 57.82 \tan z.$$

Since $r = s/60$, and $\tan z = \tan (90° - h) = \cot h$, we have

$$r = 0.964 \cot h. \tag{3}$$

The number 0.964 is almost equal to unity, and one is therefore led to take cot h as an approximation to r. As illustrated by the table, the error thus introduced is less than 0′.1 except when cot h is relatively large, *i.e.*, except when $h < 20°$.

Formula (1) is approximately the same as (3), since 0.964 is almost equal to 29/30. But (1) is much better adapted to rapid mental calculation. The discovery of (1) as a substitute for (3) is a rather natural consequence of the use of a slide rule in connection with (3). For when we set 964 opposite 1000 (using the C and D scales) it is found that 290 is almost opposite 300. It would be less convenient in practice to have (1) written in the form $r = (29 \cot h)/30$.

THE UNIVERSITY OF IOWA, APRIL 3, 1943.

Marvelous Voyages—VII

H. G. Wells' The War of the Worlds

By LAURENCE J. LAFLEUR

In "The War of the Worlds" H. G. Wells tells the story of an invasion of Earth from Mars. Mars is an older planet than Earth, and its life has evolved further. Since it receives barely half the sunlight received on Earth, and has barely one seventh our volume, it has cooled faster and is nearer its death. "Even in its equatorial region the midday temperature barely approaches that of our coldest winter. Its air is much more attenuated than ours, its oceans have shrunk until they cover but a third of its surface, and as its slow seasons change huge

snow-caps gather and melt about either pole and periodically inundate its temperate zones. That last stage of exhaustion, which to us is still incredibly remote, has become a present-day problem for the inhabitants of Mars." So the Martians determined to invade the Earth and Venus. A huge gun was cast in 1894, and light from the casting was observed from the Earth.

Some years later the gun was fired. An astronomer in Java reported a huge outbreak of incandescent gas on Mars, determined by the spectroscope to be a "mass of flaming gas, chiefly hydrogen, moving with an enormous velocity towards this earth." The same thing occurred each succeeding night for ten nights at midnight precisely; and ten projectiles were thus sent against mankind, rushing here at a speed of many miles a second.

The projectiles fell at 24-hour intervals within a limited area in England. The first was seen as a line of flame across the sky, its height at first appearance being about ninety or one hundred miles. It left a greenish streak behind it that glowed for some seconds. Some observers reported a hissing sound. The impact of the projectile produced an enormous hole, and "sand and gravel had been flung violently in every direction over the heath, forming heaps visible a mile and a half away." The projectile itself was a huge cylinder, with a diameter of about thirty yards, and was "almost entirely buried in sand, amidst the scattered splinters of a fir-tree it had shivered to fragments in its descent." Twelve hours later the metal was still glowing hot, but the top of the cylinder was being screwed off. The metal itself was yellowish-white, with an unfamiliar hue, and it was coated with a grey scale of an unknown oxide.

From this cylinder come forth the Martians, octopus-like animals with no body, but a huge head about four feet in diameter. In the head are set two immense eyes which see the same range of light rays as we do, but to which blue and violet appear black. Below the eyes is a lipless V-shaped beak or mouth, and around it two groups of eight tentacles each. The groups of tentacles serve the purpose of hands, and apparently also of legs, although apparently the Earth's stronger gravitation prevents their use for the latter purpose here. In the back of the head is a membrane which serves as an ear. The Martians have no body, no entrails, and do not eat and digest food. They feed by the injection of the blood of other creatures directly into their veins: on Earth their favorite source of this blood is man. The Martians do not sleep, and have no sex, reproducing by the budding process. Wells hints that they represent a remote descendant from a form similar to man, in which all the unimportant parts have been eliminated, and only the brain, hands, and eyes remain in a state of hyper-development. There is also a suggestion that these beings communicate by telepathy.

The Martians have trouble lifting themselves against the Earth's

gravitation, three times greater than that of Mars, although the invigorating influence of the atmosphere of the Earth tends to counter-balance this. The Earth's atmosphere contains far more oxygen or far less argon (whichever way one likes to put it) than does that of Mars. But these difficulties are overcome by mechanical means. First some handling machines are made, then extra aluminum is manufactured from clay, and finally huge war machines are prepared. These are devices about a hundred feet high, mounted on three articulated legs and possessed of tentacle-like ropes of steel for arms. It may be mentioned that the Martians had either never discovered the principle of the wheel, or did not care to use it. "Almost all the joints of the machinery present a complicated system of sliding parts moving over small but beautifully curved friction bearings. . . The long leverages of their machines are in most cases actuated by a sort of sham musculature of disks in an elastic sheath; these disks become polarised and drawn closely and powerfully together when traversed by a current of electricity. In this way the curious parallelism to animal motions was attained."

Each machine is controlled by a single Martian, who captures his own food supply and keeps it in a hamper in the back. The machines are armed with two weapons: one a heat ray projected as a "parallel beam against any object they choose by means of a polished parabolic mirror of unknown composition. . . Whatever is combustible flashes into flame at its touch, lead runs like water, it softens iron, cracks and melts glass, and when it falls upon water, incontinently that explodes into steam." The other weapon is poison gas (this was written in the last century, remember), a heavy black vapor containing an unknown element, from which escape is possible only by climbing above it or by seeking the protection of water, with which it combines chemically. It is believed that the gas combines with argon to form a compound which acts at once with deadly effect upon some constituent in the blood. In addition to these weapons the Martians experimented with planes, which, however, they never did use.

Against these machines and weapons human armies are almost impotent, largely because the heat ray explodes their ammunition. One of the Martians is indeed destroyed by a battery of field guns, another is damaged by similar means, while a third and fourth are accounted for by a torpedo boat off the coast. That was the limit of human resistance to the Martians, and mankind awaited its destruction. But salvation came from an unexpected quarter: the Martians were all "slain by the putrefactive and disease bacteria against which their systems were unprepared." Judging from astronomical observations of similar surface markings on Venus and Mars, the Martians were more successful on the inner planet and made good their landings there.

With the Martian invasion came many seeds of Martian plants, all yielding red vegetation. Only one of these succeeded in establishing

itself on Earth, and this was highly successful until it was killed off by a bacterial infection in the same way as the higher form of Martian life was destroyed.

Mankind is thus saved, save for living under the continual threat of further invasion, and benefited greatly by the study of Martian machinery.

(For *Errors* see p. 384.)

The Brightness of Comet 1942g Whipple-Fedtke

By JOSEPH ASHBROOK

During February and March, 1943, the writer observed the visual magnitude of the head of Comet 1942 *g*. This object was discovered early in December, 1942, by Whipple on Harvard plates, and was found independently on December 11, 1942, by Fedtke of the Königsberg Observatory, and on December 28, 1942, by Tevzadze of the Abastumani Observatory.

The instruments used were an opera glass of 1.4-inch aperture, magnification 4, and a field glass of 1-inch aperture, magnifying 7 times. The images were thrown sufficiently out of focus to obtain the greatest resemblance in appearance between the head of the comet and the comparison stars; the brightness of the comet was estimated by the Pickering decimal interpolation method. There appears to be no systematic difference between the magnitudes obtained with the two instruments.

Table 1 lists the comparison stars used and their adopted magnitudes in the Harvard Photovisual System, taken from *Harvard Observatory Mimeograms,* Series III, Nos. 1 and 2.

TABLE 1

Designation	Star	H.D.	M_{pv}	Spectrum
a	γ UMa	103287	2.44	A0
b	δ UMa	106591	3.28	A2
c	χ UMa	102224	3.56	K0
d	5 CVn	107950	4.73	K0
e	3 CVn	107274	5.14	K2
f	7 CVn	108845	6.14	F8
g	HR 4909	112264	5.63	Mb
h	HR 4919	112570	5.97	K0

The observations of brightness are detailed in Table 2.

TABLE 2

1943 U. T.	Estimates	M_{pv}	Remarks
Feb. 24.06	a 7 C 3 c	3.2	
25.04	a 8 C 2 c; b 7 C 3 c	3.5	
25.42	b 7.5 C 2.5 c	3.5	1
26.03	c 1.5 C 8.5 d	3.7	
27.42	b 7 C 3 d; c 5 C 5 d	4.2	
Mar. 1.15	b 3.5 C 6.5 d	3.9	
1.41	b 2.5 C 7.5 d	3.6	

1943 U. T.	Estimates	M_{pv}	Remarks
Mar. 4.11	c 7 C 3 d	4.4	
4.42	c 7 C 3 d	4.4	
5.05	c 8.5 C 1.5 d	4.6	
7.02	d 2.5 C 7.5 e	4.8	
8.06	c 9.2 C 0.8 d	4.6	
8.42	d 1 C 9 e	4.8	
9.11	c 9.5 C 0.5 d	4.7	2
9.42	d 2 C 8 e	4.8	
10.03	c 8.5 C 1.5 d	4.6	3
14.18	c 9.5 C 0.5 d	4.7	1
15.02	C = d	4.7	4, 5
15.40	d 3 C 7 e	4.9	4, 5
18.42	d 2.5 C 7.5 e	4.8	
24.05	d 3.5 C 6.5 e	4.9	
25.03	d 6 C 4 e	5.0	
26.04	d 7 C 3 e	5.0	
30.04	e 7 C 3 f	5.8	5
30.06	e 6 C 4 f	5.7	5
31.03	e 7 C 3 f	5.8	5
Apr. 1.15	g 7 C 3 h	5.9	5

REMARKS

1 Bright moonlight; 2 slightly murky; 3 slight moonlight and possible cirri; 4 bright moonlight and slight haze; 5 field glass used. Unless otherwise stated, the opera glass was employed.

The comet passed through perihelion February 6, 1943. During the interval of observation the heliocentric distance increased from 1.38 A. U. to 1.57 A. U., and the geocentric distance from 0.50 A. U. to 0.73 A. U. The observed decline in brightness over this interval of time was 2.7 magnitudes.

The usual assumption that the brightness of a comet is inversely proportional to a constant power of the radius vector implies that the magnitude (after reduction to unit geocentric distance) can be plotted as a linear function of the logarithm of the radius vector. The above observations indicate that such is not the case for this comet, but that an additional variability occurs. This behaviour is typical; of the 45 comets studied by Bobrovnikoff (*Perkins Contribution* **16**, 1942), such additional variability is indicated in 38 cases.

HARVARD COLLEGE OBSERVATORY, (LEESBURG, VIRGINIA), JUNE, 1943.

GENESIS

Once in an infinite, stark loneliness
Of unformed atoms and untroubled space
Eternal Will, blind, inarticulate,
Inchoate in the dark, eventless void
Found utterance in a vast, poignant flame
Which, dying, echoed world's, and blazing suns,
And stately galaxies, and light, and life:
That through their interplay might come to be
One sentient thing—one moving mite that in
Its pride of mimicry should learn to think
In miniature the thoughts that gave it being—
One who should love, and loving learn of God.

Granville, Ohio. J. H. RUSH.

The New Zealand Method of Observing Star Colours*

By A. G. C. CRUST

This Memoir is undertaken to fill an admitted gap in the astronomical world's knowledge of the binary stars. The case is a conspicuous one of observational selection, namely the selection of eclipsing binaries according to relatively large range of magnitude, as pointed out by Aitken, and confirmed by Russell's remark on the absence of "white dwarfs" from known eclipsing systems (Aitken, "The Binary Stars," 2nd Edition, p. 199).

The study of colour variations rectifies the position and probably complements the selection very efficiently, for mutual eclipses in almost any pair of stars of different temperatures are readily detected by our colour method and actually the "white dwarf" companion (really an intensely blue or perhaps violet star) appears to be the normal companion of the true "single-lined" spectroscopic binary.

The discovery of colour variations in New Zealand is proceeding so rapidly and has been so neglected overseas that the whole study remains a flourishing local monopoly and in future, as an amateur, the writer is able to provide an ephemeris for New Zealand only. There appears no reason, however, why further attempts should not be made to convey the information available to astronomers overseas, and still less reason why these "signs in the stars," whatever their meaning, should in effect be suppressed through ignorance of methods almost within reach of many of the humblest amateurs.

It is with much pleasure that the writer is therefore able to issue this Memoir with the conviction that he is repaying in some small measure a debt that he owes eventually to the Divine Author of all wisdom and knowledge, and directly to many eminent astronomers overseas.

The method of colour observation is difficult to describe in a way that conveys exactly what is required, but extremely easy to demonstrate, given reasonably good sky conditions. The results are extremely definite and would not otherwise appeal to the writer's temperament.

It would seem that these colour phenomena have been overlooked because colour sense training has not been regarded as a precise branch of physical science. The writer is beginning to contemplate the possibility of colour variations in the stars being eventually recognized by people of normal colour vision rather than by the astronomical world. When questioned as to the utility of these observations one is tempted to retort in these times that, of course, they are of no value in killing people, yet

*Memoir No. 10 of the Star Colour Section of the New Zealand Astronomical Society.

they lead to results, *e.g.*, stars of high density, which are at no disadvantage as regards reality compared with our own somewhat flimsy world. Also they provide for discussion subjects which are of no value as such to the enemy, at times when few matters can be discussed freely.

Precautions against Error, and General Method

In undertaking visual star-colour observations, several sources of error must be borne in mind and as far as possible eliminated. The New Zealand method is essentially that proposed by the late Professor W. H. Pickering (see Popular Astronomy, 1917, Aug.-Sept.). The adoption of a more uniform scale was among the suggestions made and, to this end, the intervals between the divisions on Professor Pickering's original scale were compared by means of pieces of bluish and yellowish glass. Also colour measurements of some first magnitude stars were made and plotted against the corresponding colour indices given in *H. A.*, Vol. 50. The plotting gave a discontinuous curve as the gradient changed at every scale division, and could be checked by the above-mentioned comparisons of intervals. Finally "uniform" values were assigned to the actual coloured discs, so that the curve of "uniform" values plotted against colour indices became a straight line. Observations were extended to other stars (the brighter ones of type N) and later the uniform values of colour were correlated with the colour indices quoted for the various spectral types by Russell, Dugan, and Stewart ("Astronomy," Vol. II, p. 734). For actual observations, crayon scales of improved uniformity have been prepared.

Though various experiments have been made the great bulk of the observations have been produced with careful attention to the following rules:

1. The observer must work in darkness, his eyes being influenced only by the colours of the star images (put out of focus by the low power eyepiece being racked out towards the observer), and those of the colour scale. The recording should be made not too near a bright light.
2. The star image must resemble the scale image closely in brightness.
3. Owing to the increased reddening due to low altitudes, care must be taken to observe at a moderately high and fairly constant altitude, and to avoid any apparent mist, smoke, or regions affected by auroral colours.
4. All observations are referred for comparison to "standard stars," the colours of which are well known from repeated observations.
5. All observations are reduced, by calibration table appropriate to the actual colour scale used, to the theoretical "uniform scale."
6. Mean colour corrections (latterly weighted) are obtained and applied to all stars observed on any evening. When these corrections have been applied, the results are catalogued. Latterly probable errors have been computed for use in revision of the catalogue.

To satisfy our first principle, a narrow shaft of light is allowed into the telescope room and reflected wherever required by a common plane mirror. External lights are excluded as far as possible and the observing eye is protected from impact of the shaft itself or its reflection. The mirror is usually omitted in outdoor observing with small instruments.

Secondly, the star images are observed out of focus as recommended by Professor Pickering, and their intensities can be varied by varying the focus. Also the scale illumination can be varied by varying the power of the lamp or its distance (via the mirror) from the scale, and by varying the inclination of the scale itself. To bring out the colours most strongly, the intensity requires to be considerably less than that required for reading (see Appendix A). The scale is conveniently held in the left hand while the right hand controls the telescope and protects the eye from external lights when necessary. It is preferable to confine observations to a rather limited range of magnitudes, *e.g.*, for telescopes of about 2 inches aperture, observe 1st and 2nd magnitude stars, for 5-inch, 3rd, 4th, and 5th magnitudes, and for 9-inch, 5th and 6th magnitudes.

The third rule is also of meteorological interest, since the atmospheric reddening is likely to be far greater in a "warm air mass" than in a "cold air mass," so that the clear nights following the subsidence of a cold air mass are especially valued at Wellington. However the practice of keeping a constant altitude is particularly easy when, as is usual in New Zealand now, a star variable in colour is under observation. The usual period of observation is about one hour, and it may be subdivided into three periods of 20 minutes each. Suppose that the variable is at an altitude of about 30° or 40° and is between NE and SE. For 20 minutes stars a few degrees above it are observed alternately with the variable, then for 20 minutes stars about the same level as the variable, and finally, the series is closed with stars below the variable. If the variable is in a similar position between NW and SW, stars below it are observed in the first 20 minutes, then stars at the same level, and finally stars above it.

For variables conveniently placed near the meridian, it is generally easy to find comparison stars which may be taken in any order but should not differ greatly in altitude. The lower the altitude, the more strictly should the same level be adhered to.

The fourth principle involves the use of stardard stars, which at first were merely stars frequently observed by the Section. The values obtained were catalogued and all given equal weight. Latterly the "VKF" Catalogue of Colour Equivalents by Kukarkin (*Publications of the Sternberg State Astronomical Institute,* Moscow, Vol. X, pt. 2) has been used as it comprises world-wide colour results and gives the relative weight assignable to our own observations. The weighting subsequently made possible and adopted, also the segregation of recognisable

colour variables, should increase the value of our own observations, but this matter can be left over to the compilation of a future catalogue from world-wide sources (see Appendix B). Standard stars are so numerous now that even in far southern declinations observers can use the Sternberg values down to the 2nd or 3rd magnitudes and our own determinations are available for most of the remaining stars at all prominent to the naked eye.

For the fifth rule, a calibration table is issued to observers and a copy retained by the director of the Section, as in practice so far the reduction is left to him.

The sixth principle brings us to the results from which an idea of the reliability of the observing can be formed. The mean colour correction cannot easily be determined by any observer, because it is impracticable to issue frequently the changing standard colour values of the stars. It is not considered likely that, under conditions that can reasonably be assumed constant, measures should vary more than about 0.30 of a uniform scale division on either side of their own mean. Accordingly the colour corrections required to change the observed to the standard values are grouped by applying ± 0.30 as a selection limit. Stars can evidently thus be excluded from the main group which usually appears in any extended series of observations, though the observing conditions may appear perfect, since the same sort of discrepancy is found in the calibration of colour scales. Here two scales are compared side by side and the only source of variation must be of a personal origin. But while admitting this personal source of variation, we must also admit, in stellar observations, the possibility of variation in the stars themselves, though this was recognized in supposedly constant stars by the writer only after seven years of observation. The major variations so far found by persistent observations are *not small;* they are usually equivalent to the greater part of a scale division. They might easily indicate a change of spectrum from type B0 to A0. Differences similar to these changes are readily noticeable in fading Air Force insignia, but in these stars they are effected in a few minutes.

The statistical "probable errors" of the mean colour correction usually are about 0.09 of a uniform division for the main group in any series of results. In smaller groups they may vary from 0.01 to 0.17. The large group often consists of about a dozen stars and sometimes includes all the standards observed, but one may well suspect that some of the smaller groups are due to a conspiracy of real variations with merely personal and atmospheric ones. It is clear, however, that real variations are often much larger than any possible "probable error," and the behaviour of a star which changes so much in a definite (and sometimes inconvenient) period must be as obvious to the trained colour observer as the crudest of coloured traffic signals are to anyone of normal but untrained colour vision.

Colours of the Uniform Scale and the Spectrum

The probable error of 0.09 is likely to be close to the mean for all our weighted series of measures. It will be determined more exactly when it is possible to revise our catalogue. What does such an error imply in terms of spectral colours? Let us consider the scale itself. It consists of twelve colours arranged as follows:

5. Cobalt Blue	9. Pale Yellow	13. Orange
6. Prussian Blue	10. Chrome Yellow	14. Vermilion
7. Turquoise Blue	11. Gamboge Yellow	15. Scarlet
8. Pale Blue	12. Pale Orange	16. Blood Red.

The spectral colours, red, orange, yellow, green, blue, and violet, diverge from the scale only by replacing pale blues and white by various shades of green. Near the ends the colours are very similar. If, following the Smithsonian Physical Tables (7th revised edition, 4th reprint, table 319) we take the typical blue colour to have a wave-length of 0.47 microns, the typical red colour 0.71 microns, and assume that these values represent the uniform scale values 5 and 16, then we have a range of 0.24 microns divided into the eleven intervals of the uniform scale. Each interval is then equivalent to 0.022 microns or 220 Ångstrom Units, and the probable error of 0.09 division is equivalent to only 20 A.U. The writer found in 1923 under laboratory conditions at the University of Otago, that he could easily distinguish spectral colours differing only by 20 A.U.

The Argelander Method of Comparison Applied to Colours

The degree of accuracy to which the scale divisions are subdivided in observing is represented approximately by 10 A.U., *i.e.*, about 0.05 of a division. This is attained by employing the Argelander or step method in colour comparisons, the value of the "step" itself being varied from 0.05 to 0.33 of a division. Indeed we may have two equal "strides" of 0.50 each.

As with magnitudes when observing the brightness of variable stars, the observer estimates that the colour of a star is, for example, so many steps above 7.0 and so many steps below 8.0. For beginners especially the following table is recommended and in the course of observational practice may easily be committed to memory.

Argelander Step Intervals and Corresponding Colour Values to Two Places of Decimals

The writer finds the practice of making the Argelander step so elastic a great asset also in comparing the magnitudes of variable stars, especially in the eclipsing systems of extremely small range revealed by their colour variation. In this table, the number "x" is given the value of the coloured disc immediately below (*i.e.*, bluer than) the star observed.

Decimal Reading Up	Fraction	Argelander Steps	Decimal Reading Down
x + .00	Identical	.....	x + 1.00
.05	1/20	1 + 19	.95
.10	1/10	1 + 9	.90
.14	1/7	1 + 6	.86
.17	1/6	1 + 5	.83
.20	1/5	1 + 4	.80
.25	1/4	1 + 3	.75
.29	2/7	2 + 5	.71
.33	1/3	1 + 2	.67
.40	2/5	2 + 3	.60
.43	3/7	3 + 4	.57
.50	1/2	1 + 1	.50

The observer, having matched the brightness of his star image and relevant scale colours suitably, may first gain the impression, for example, that the star is above 7.0 considerably, and not so far below 8.0. Two or three trials of different numbers of steps should be made, and with practice this can be done quite quickly. The writer finds it best to estimate steps always from the scale division nearest to the actual colour of the image. In this case try two steps down from 8.0 and see if three more would appear to give 7.0. If not, *e.g.*, if the three steps would give a colour lighter than 7.0, try two steps down and five more, and see if the five steps lead to 7.0. If now the five steps lead to a deeper blue than 7.0, try one large step down and two further steps of the same size. If these lead to a colour identical with 7.0, we have the result, 7.67. Had the other trials been successful, the results would have been 7.60 and 7.71 respectively. It may be noted that with one exception, the total number of steps used does not exceed ten, and this is in accordance with the usual established practice in observing magnitudes by the Argelander method. The values indicated by the decimals 0.05 and 0.95 can, however, be regarded as at least bordering on the distinguishable, just as is a difference of 10 A.U. in a spectrum. The writer, in observing, thinks of the difference rather as 7.0 and "a very little bit," or "not quite 8.0," but, at least in his opinion, not exactly 7.0 or 8.0, and equally, not as much as 7.1 or as little as 7.9.

From our recorded results we might be criticized for going far beyond the possible limits of accuracy in stating these results to two decimals. However it is not claimed that the second decimal place is more nearly accurate than the above step-table would suggest. Conceivably an observer may consider neither of two adjacent series of steps applicable and therefore adopt the intermediate decimal, but the use of the second decimal in any case is dictated merely by convenience and the impossibility of making use in calculation of such an expression as the observer's actual thought, *e.g.*, "8 and 2 steps down to star; 5 steps down to 7; no; 8 and 1 large step down to star, 2 large steps down to 7, neither applicable," when that can be represented by 7.69. Any value to two decimal places is conceivable after the conversion to Uniform Scale has been made, and the Sternberg values are quoted to two

decimals, though even here the second decimal is not known exactly because of the nature of the regression equation (see Appendix B).

Some beginners simply make estimates to one decimal place, but it can readily be seen that the values obtained by the Argelander system are just as accurate. Further, when colour variations are being studied, it is found that the fractional values tend to produce smooth curves when plotted against the time.

Reality of Colour Variations

As certain objections of a psychological nature have been raised against our method, objections essentially the same as the "deception by demons" to which Galileo's discoveries were attributed, it should be pointed out here that, though predictions of colour variations are made annually, the initial discoveries on which these predictions are based are necessarily the result of repeated and persistent observation without the help of any ephemeris. Indeed an ephemeris based on a spectroscopic period is seldom useful for more than a single observing season, as radial velocity and eclipse periods seldom agree at all closely. Also the cause of a radial velocity oscillation may produce only one of a number of series of eclipses as in ρ Hydrae, or it may be quite different from the cause of eclipse, as in α Pavonis.

The objection to the method as a "visual" one is rather dangerous for the critic, since "colour" is, after all, a visual phenomenon, and he is really forced to assert that pronounced fading in common coloured objects is only a psychological effect, if he is to sustain his objection.

The attitude of the observer should always be that, if there is no ephemeris, a colour variation may happen at any time in a star selected for repeated observations, but he is always prepared to record passively and faithfully the colour changes which he actually sees. A change of about 0.1 of a scale division, being similar to the probable error, is not necessarily evidence of variation, and a return to the original value at the next observation is quite likely. A series of values thus oscillating closely about a mean value is therefore treated as a series of determinations of the normal colour of a star.

On the other hand, a change of 0.1 of a scale division in an interval of four minutes may possibly be real, and if so, a further change in the same direction may be found after another 4 minutes have elapsed. Usually stars suspected to be varying are observed at 4-minute intervals, for with some experience an observer finds that a single observation and recording occupy about 2 minutes, and standard stars are observed alternately with the suspected variable.

The star may remain sensibly constant for a part of the observing period, and later show a definite change in colour. In either case it is then interesting to see whether the colour attains a value which is again sensibly constant for at least two observations, or whether, after reach-

ing an extreme maximum or minimum value, it returns steadily to normal again. Usually the rate of change in an eclipsing variable is fairly constant, but not necessarily the same before and after a maximum or minimum. In case the observer should be tempted to make his colour changes artificially uniform, he is deterred by the fact that the Argelander step method does not give him a series of values at exactly uniform intervals, *e.g.*, 0.29, .33, .40, .43, .50, and also by the fact that if passing clouds upset his programme, or if his timing is upset by any delay, even an approximately uniform series of values is not to be expected. Further, since the actual scale intervals vary, the same intervals do not necessarily appear on either side of a certain scale value, when the variation is actually uniform. For instance, in making crayon scales, the writer finds it difficult to avoid making No. 7 slightly too blue, with the result that the interval between 7 and 8 is very apt to be greater than that from 8 to 9.

Ephemeris and Classification of Colour Variables

Though eclipse variations show fairly definite characteristics of uniformity, it cannot be assumed that definite colour variations are due to eclipses unless they are repeated in a certain period which is definite and sensibly constant. From this point of view it is essential that the times of observation of the variables, or suspected variables, should be determined and recorded by the observer with considerable accuracy. It is sufficient to record them to the nearest minute but practicable to record to the nearest tenth of a minute (expressed by a decimal). Watches with second hands and small rates can be checked by radio time signals, supplied in the New Zealand region to users of ordinary broadcast radio sets through 2YA, Wellington, and 2FC, Sydney, from the Dominion Observatory, Wellington, and the Melbourne Observatory, respectively. Latterly time-signals have largely displaced the chimes formerly broadcast by 2YA.

The difficulty of obtaining sufficient observations to determine the nature of colour variables is freely admitted and if critics consider the Ephemeris to be based on too few observations (they are incidentally too numerous to publish save at the expense of both Ephemeris and Memoirs), it may be asked what more can be done to improve the situation? The phenomena are very far from being so vague that the observer can be forced to see what is predicted. There are some excellent tests on this point, *e.g.*, Hobbs' discovery of a deep colour minimum (instead of a predicted maximum) in ϵ Normae. There is not a shadow of doubt that here a second eclipsing partner is indicated. For some years amateur and professional astronomers have been appealed to for assistance on grounds ranging from scientific and national interest to motives of sporting competition and intellectual pleasure. The writer remains deeply impressed by the smallness of the number of people who obviously enjoy watching the stars. At the same time valuable help and

information have been given by some professional astronomers, especially in regard to the Catalogue. The changeable sky conditions of Wellington are almost a constant hindrance to both observation and demonstration, but we have obtained most valuable help from Chrisp and Hobbs of Dunedin, where most of the predictions of the 1941 Ephemeris of Eclipsing Colour Variables have been confirmed. It is quite practicable to divide our colour variables into two classes—the eclipsing variables suitable for an ephemeris and the other variables, which are more or less irregular. The former class are definitely valuable standards of colour whenever their colours are constant—the others require to be used only with due caution. An assurance that the colour of a star is normal also guarantees that the magnitude shall be normal. Thus on November 10, 1942, the magnitude of Rigel was guaranteed by colour observations, for the comparison of the newly discovered Nova Puppis. Previous to the comparison Rigel exhibited a colour minimum. The writer suggests that this definitely fruitful colour research can be speeded up, on an amateur basis, only by the help of more observers, the Ephemeris giving all predictable variations for New Zealand and containing data for extension by observers abroad. The curtailment is regretted but the interests of New Zealanders who are actually confirming the Ephemeris by observation must have the first consideration.

Our knowledge of the classes of colour variables ineligible for the Ephemeris must remain scanty. There are probably many stars which change colour irregularly though the magnitude is nearly constant. The yellow and reddish stars (spectral types K, M, and N) will probably prove notorious in this respect, but bluish examples (types B, A, and F) are certainly known. It is largely in these hotter types that eclipsing variables suitable for our method of study occur. In view of the difficulty introduced by irregular variation in the cooler stars, and the fact that the colour properties of telescopes vary immensely, observers are advised to depend mainly on the more bluish stars as standards. In speaking of bluish stars, we are conscious of a deep cleavage of opinion and experience, since some colour observers abroad seem quite unable to see any blueness in the stars. The extreme absurdity of the position seems to us the general acceptance of the term "white dwarf." Such a star is much hotter than Sirius, which is recognized as a blue star quite commonly even in England, so that if the term "white dwarf" has any colour significance at all, it must indicate "deep blue" or even "violet" dwarfs observable as such under really clear sky conditions and through nearly neutral-tinted glasses. The Star Colour Section has nothing so inaccurate for the astronomical world to accept as this wretched term "white dwarf," which has obviously been adopted in a most uncritical spirit. Not only is it obvious to the naked eye in New Zealand on a clear night that many stars are blue, but it is difficult to conceive meteorological conditions that could substantially alter this condition. Only

the presence of a great deal of smoke haze from numerous factories can be supposed to be capable of making the blue stars appear white to the naked eye.

Difficulty of Forming Pre-Conceived Ideas

Since telescopes and atmospheric conditions vary greatly in colour properties, while no star can now be safely regarded as "colour-constant," observers cannot be influenced too much by pre-conceived ideas of the colours of the stars. The writer is determined to record just what he sees and to keep a mind open to evidence of variation. This is the real discipline to which the Section owes its obvious and demonstrable successes. He has used five different telescopes. To form a pre-conceived idea of the colour of a star would involve a singularly useless calculation, some of the factors in which, *e.g.*, the effect of haze, smoke, and aurora in the air, could be known only very imperfectly. The elaboration of useless ideas can not be allowed to usurp the functions of careful and persistent observation. In one evening's observations, the use of different telescopes or even different eyepices is not recommended. The series taken under different instrumental conditions must be reduced separately, and far more convincing results are obtained in about one hour's scrutiny under conditions made as uniform as possible. Sometimes two series are taken at different altitudes.

Treatment of Colour Variables

The treatment of observations of stars varying in color involves an additional listing of results, besides the ordinary cataloguing. If there are several values of mean colour correction, it is usually obvious that the value applicable to the star on the normal part of its observed curve is also applicable to the other values. If little is known about the variation, it is not always easy to decide whether the colour is normal or not during a given constant phase, *e.g.*, a decrease of colour may separate a maximum from a normal phase or a normal from a mimimum phase, and if small it may be connected with minor phenomena such as reflection effect, or minor irregularities.

By attention as frequent as the weather will permit, by the use of a spectroscopic period if available, and by plotting the colour curves reduced to the opposition of the star (see Appendix C), the periods of several eclipsing variables detected by this colour method have been elucidated, and form the subject of the annual "Ephemeris of Eclipsing Colour Variables" issued by the Star Colour Section. This expanding publication now covers 13 foolscap pages and during the war years at least only four type-written copies are sent outside New Zealand, eight being distributed to New Zealand observers. The expansion of this Ephemeris in itself is a problem, for the time available for typing is limited and the demand insufficient to warrant other methods of reproduction. The tables must now be reduced to cover only the phe-

nomena observable from New Zealand, no overseas demand having developed. The Ephemeris provides the answer to critics who frankly disbelieve in the Section's achievements, for it provides numerous epochs at which our results can be checked by any observable eclipse phenomena. Lack of equipment in New Zealand has compelled us to rely on our own colour measures, confirmed notably in 1941 by Chrisp and Hobbs at Dunedin. It is hoped that soon also photometric confirmation may be obtained there by K. D. Adams.

The variation of magnitude accompanying the colour changes we have noted as being in general very minute. Therefore there are few eclipsing systems for which magnitude epochs can be determined satisfactorily, say to the nearest 0.001 of a day. A rather unusual case is ρ Hydrae, which is subject to partial eclipses of rather long but variable duration, and is provided with excellent comparison stars, δ, η, and σ Hya, from which in Argelander comparisons the magnitude can be seen to vary in steps of 0.03 magnitude. It is a most commendable test for the ability of variable star observers using the Argelander method. The magnitudes of δ, η, and σ Hya are 4.18, 4.32, and 4.54, respectively. The eclipses became total and annular in 1942.

In general, then, the colour variations of these newly discovered variables are incomparably more suitable for determining definite epochs for an ephemeris than are the corresponding changes of magnitude. The procedure resembles the customary treatment of magnitude variations, in that the colour curves are plotted against the time given in Julian Days and decimals (reduced to opposition) on such a scale that the epochs can be found to the nearest 0.001 day. Repetition of the same variation leads to the finding of multiples of the period by simple subtraction, and ultimately to the period itself. Since the colour variations at the primary and secondary minima of magnitude are in opposite directions, these eclipse phenomena are easily distinguished and are of further assistance in determining the period. Also the epochs at which the changes of colour begin and end, *e.g.*, the beginning and end of a maximum indicating a total eclipse, are usually quite sharply marked and quickly provide a large number of definite epochs from which the period can be determined with precision.

The Dunedin observations of 1941 have shown that our Ephemeris predictions do stand up to the test of observation, and also the periods of the following stars as spectroscopic binaries correspond well enough with our periods for colour variation, which of course are being improved whenever they can be checked at Wellington or Dunedin.

Comparative Periods of Eclipsing Spectroscopic Binaries

As Dr. Joel Stebbins has pointed out (*Ap. J.*, **39**, 447), spectroscopic and eclipse periods though well established do not necessarily agree. In the list above δ Ori, α Vir, and δ Lib are already recognized abroad as

Star	Spectroscopic Period days	Colour Eclipse Period days
Beta Ori	21.90	21.38270
Delta Ori	5.732595	5.732494
Mu Ori	4.44746	4.451204
Rho Hya (one period)	8.24	8.24585
Theta 2 Cru	3.4280	3.440777
Alpha Vir	4.04160	4.011434
Delta Lib	2.32735	2.32632

eclipsing variables, the former two being fairly typical of the class we are discovering, while δ Lib is a typical "Algolid" with a range of 1.1 magnitude. The range of δ Ori, in agreement with overseas observers, we find to be about 0.10 magnitude, while in the case of α Vir we confirm Stebbins' finding of an eclipse period definitely shorter than the spectroscopic one.

Comparative Magnitude Observations of Eclipsing Variables of Small Range

The difficulties which arise in determining very small ranges of magnitude, especially in stars as bright as the 2nd magnitude, are well illustrated by α Pavonis, the range of which is only 0.04 magnitude.

For colour observations small changes of magnitude are advantageous, but for determining the change of magnitude itself, the difficulties are such that variable star observers are discouraged from attempting such delicate observations. Further, extremely favourable sky conditions are essential, but they are provided at Wellington sometimes, and it is then possible to make visual comparisons between the variable and other stars so accurately as to provide quite a good value at least for the *range* of variation. In choosing comparison stars it is desirable to select stars similar in colour to the variable, and temporarily near the same altitude, one a little brighter and the other a little fainter than the variable. For a bright star such as α Pav it is not always easy to find suitable comparison stars, but when this variable is in the SE, we may choose ε Sagittarii, of magnitude 1.95, and σ Sgr, of magnitude 2.14. The difference of 0.19 magnitude may be divided into five steps. Now the main changes of colour in α Pav are shown by careful comparisons to cause a change of magnitude of only one step or 0.04 magnitude. Such observations must be made before and after a predicted change of colour to or from the colour maximum, the small change in magnitude being then evident at once. Magnitude comparisons taken at random of such exacting objects do not give satisfactory results, nor should they be expected from amateurs with many other pressing interests.

Conceivably the range estimated as 0.04 magnitude could just as easily be 0.03 or 0.05 magnitude, but since a well-trained colour observer is accustomed to varying his Argelander steps, it is unlikely that an error even so small as this could occur without causing the observer

to revise his steps so as to give a result with a greater appearance of "reality." When α Pavonis is in the SW, Sagittarius is very low, but for comparison then we have α and β Gruis most favourably placed. Once again, these stars confirm the value 0.04 as the range of α Pav.

As standards of comparison, it is admitted that two of these stars may be somewhat defective. σ Sgr occasionally shows irregular colour changes, which probably imply slight changes in magnitude. Fortunately the variable is much nearer in brightness to the other standard, ϵ Sgr. Again, β Gru is orange in colour (type Mb), and possibly slightly variable.

α Pavonis, therefore, is one of our most difficult stars from the magnitude point of view, but if we admit that our range may be 0.01 magnitude in error, it may be recalled that the Harvard magnitudes themselves though given to two decimal places, are not claimed to be accurate to the nearest 0.01 magnitude. It does not seem likely that better results can be obtained by such comparative methods.

The actual values derived from comparisons with ϵ and σ Sgr were 1.99 and 2.03. If the Harvard values for these two stars are in error, it appears that, if the error is less than 0.03 magnitude in opposite directions, so that their difference is in error by less than 0.05, they cannot give a range in error by as much as 0.01 magnitude. Thus, if instead of 1.95 and 2.14, we had 1.93 and 2.16, the comparisons ϵ 1 V 4 σ and ϵ 2 V 3 σ would give 1.99 and 2.03 as before, but magnitudes 1.92 and 2.17 would give 1.97 and 2.02. On the other hand the range would contract to 0.03 if the actual values of the comparison stars were 1.98 and 2.11. As the magnitudes of α and β Gru are 2.16 and 2.24, and comparisons give 2.20 and 2.24 as the magnitudes of the variable, in this case errors of 0.01 in opposite directions in the Harvard magnitudes of the comparison stars would give the same error in the range of α Pavonis. The mean of the maxima thus determined, 2.10, is only 0.02 magnitude different from the Harvard value of 2.12 for the photometric magnitude of α Pavonis.

In concluding this discussion of observational methods, the writer asks readers to remember the extent to which the subject is like an uncharted sea. There is practically no basis for preconceived ideas, even the spectroscopic periods being seldom close to the eclipse ones, while maximum and minimum colour values are unknown abroad, where both the magnitudes and the colours of the stars are assumed constant, in the absence of the knowledge accumulating now in New Zealand, and tending from its very copiousness to become a local monopoly.

The Interpretation of Eclipsing Systems

In this Memoir the writer has preferred not to burden the text with mathematical expressions.

The writer claims to be a physical observer rather than a mathema-

tician and he does not feel required to introduce anything very complicated into this paper. To determine orbits we would require much more complete curves of colour variation than are likely to be available for a long time to come, so numerous are the objects presenting themselves even for classification. Then we should require to know all about the relationship between colour and magnitude before being able to apply established methods of determining orbits. Therefore we prefer to work directly from our carefully measured values of maximum colour and range of magnitude, and other data accepted abroad. For those who cannot follow the reasoning, it must suffice to say that a very small range of magnitude and colour changes of the considerable extent observed imply that the changes are due to relatively small, very hot and very dense companion stars, the details of which are given in the concluding table.

These conclusions are based on the accepted values for the apparent magnitude and distance of each system, and in most cases the normal colour of the system is derived mainly from the Sternberg (VKF) Catalogue, with the addition of our later observations. The maximum colour values are of course our own, being the means of values obtained during the constant maximum phase. Though small errors in the ranges of colour or magnitude could influence the results considerably, the general conclusion given above is quite well supported.

The distances of the stars are represented by their "parallaxes," which are the small angles subtended by the radius of the Earth's orbit around the Sun as seen from the stars. This arises from the fact that the diameter of the Earth's orbit is used as the only adequate base-line for measuring the distances of the nearer stars, and that the parallax so obtained is sometimes large enough to be important in practical astronomy. In most cases our variables are so remote that the parallaxes are too small to measure effectively by the "trigonometric" method just referred to, but "spectroscopc parallaxes" are available. These are based on differences in the dark lines of stellar spectra which are due to differences in the actual luminosities of the stars.

The actual brightness is commonly denoted by the "absolute magnitude" M, the apparent magnitude by the "apparent magnitude" m. The absolute magnitude is the apparent magnitude which a star would show if placed at a distance of 10 parsecs, *i.e.*, if its parallax were 0″.10. The Sun's magnitude at this distance would be about 4.9.

Now $M = m + 5 + 5 \log$ (parallax) (log of parallax in ″ to base 10).

Taking the Sun as the unit of luminosity, we may speak of "sunpower" just as we speak ordinarily of candlepower, and

$$\text{Log (Sunpower)} = 0.4\ (4.9 - M).$$

Thus a star of $M = -0.1$ is 100 times as bright as the Sun, since Log (Sunpower) $= 0.4\ (4.9 + 0.1) = 2.0$, which is log 100.

Spectroscopic parallaxes are liable to a probable error of about 20 per cent. Errors in the parallax, for which of course we are not responsible, would alter the linear dimensions of our systems in proportion to the errors in distance, and affect both components equally.

The diameter of a star is a function of its absolute magnitude (or sunpower) and its colour. The colour index is the difference between the photographic and the photometric magnitude, and is positive if the former is the larger, negative if the latter is the larger (numerically).

In a total eclipse we are left with the colour and magnitude of the larger star only during totality, but at normal colour and maximum magnitude we have the combined light and colour of the two components.

The correlation coefficient between Uniform Colour (C) and Colour Index (I) obtained in 1937 was +0.996, (+1.000 would indicate perfect correlation) and the regression equation was

$$I = 0.372C - 2.71 \quad (\text{or } C = 2.69I - 7.28)$$

The indices were those given by Russell, Dugan, and Stewart (Vol. 2, p. 734) for spectral types B0 to N. Thus uniform colour values can be changed into colour indices by multiplying them by 0.372 and subtracting 2.71. We can find out the colour index and absolute magnitude of the companion star as follows:

Let the suffixes 0, 1, and 2 refer to the combined system, the primary, and the secondary, respectively, thus:

M_0 is the combined photometric absolute magnitude.
M_1 is the photometric absolute magnitude of the larger star.
M_2 is the photometric absolute magnitude of the smaller star.

Now let S = photometric sunpower [$\log S = 0.4\,(4.9 - M)$]
I = colour index [$\log H = 0.4\,(4.9 - G)$]
G = photographic absolute magnitude.
H = photographic luminosity corresponding with G.

Then M_1 and M_2 combine to give M_0
by $S_1 + S_2 = S_0$ (or $S_2 = S_0 - S_1$)
I_1 and I_2 combine to give I_0
Adding $M + I$,
G_1 and G_2 combine to give G_0
by $H_1 + H_2 = H_0$ (or $H_2 = H_0 - H_1$)

Now as S_2 and H_2 are obtained by subtraction, they give us M_2 and G_2 by the sunpower-magnitude formula, and $G_2 - M_2 = I_2$. Thus we have all the quantities in the expressions given above.

As an example let us take Alpha Pavonis. The data required are the normal magnitude, range, parallax, normal and maximum colours.

The normal magnitude according to the Harvard measures is 2.12, and the parallax according to Dr. Schlesinger's (Yale) Catalogue of parallaxes for 1930 is 0".014 (spectroscopic). By the formula $M = m + 5 + \log p''$,

$M_0 = -2.15$, and applying the range of 0.04,
$M_1 = -2.11$.

The normal colour (uniform) is 6.43, the corresponding colour index being —0.32, while the maximum colour is 7.01, or colour index —0.10. Therefore the above literal expressions become:

(M)		—2.11 + 1.40 combine to give	—2.15	)	$M_1 = -2.11$
(S)	by	637 + 25 =	662	)	$M_2 = +1.40$
(I)		—0.10 — 2.19 combine to give	—0.32	)	$I_1 = -0.10$
(G)		—2.21 — 0.79 combine to give	—2.47	)	$I_2 = -2.19$
(H)	by	699 + 189 =	888	)	$C_2 = +1.38$

The actual diameter of a star is obtained according to Russell, Dugan, and Stewart (Vol. 2, p. 737) by the formula:

$$\text{Log } R = 0.82\ I - 0.20\ M + 0.51.$$

If we wish to work directly from the uniform colour, we deduce from this equation and the regression one:

$$\text{Log } R = 0.305\ C - 0.20\ M - 1.71.$$

This gives us the diameter of the primary R_1 directly from the maximum uniform colour, but the former equation is required for R_2.

It is pointed out by Russell, Dugan, and Stewart that it is quite sufficient to give the diameters derived from the former equation to two significant figures. If therefore we proceed to deduce the density of the secondary, assuming that Eddington's Mass-Luminosity Law is strictly applicable, we have to evaluate W_2/R_2^3, where W = mass, *i.e.*, to divide the mass by the cube of the diameter.

Having found from the mass-luminosity curve (Eddington) W_2, corresponding with M_2, we take log W_2, and already we have log R_2 from the equation above.

Then log (density) = log W_2 — 3 log R_2.

This obviates error in converting log R_2 to R_2, but it would seem amply sufficient to state the density just to one significant figure.

Such a value may be conservative as dwarf stars of high density are sometimes more massive than the mass-luminosity law would imply (*e.g.*, the companion of Sirius).

If now we use the data for Alpha Pavonis in the above diameter formulae, we have:

$$\text{Log } R_1 = 0.305\ (7.01) - 0.20\ (-2.11) - 1.71 = 0.852,$$

whence $R_1 = 7.1$ (The Sun's diameter is the unit),

$$\text{and Log } R_2 = 0.82\ (-2.19) - 0.20\ (+1.40) + 0.51 = \bar{2}.43,$$

whence $R_2 = 0.027$.

The masses corresponding with M_1 and M_2 (here —2.11 and +1.40) are 8.4 and 2.3, respectively, according to Eddington, whence the densities are $D_1 = 0.018$, and $D_2 = 120{,}000$. These are in terms of the Sun's density as unit. Taking the density of water as the unit, the specific gravity of the secondary becomes $120{,}000 \times 1.41$, or 170,000.

The effect of errors in the range of magnitude may be illustrated by assuming an error of ±0.01 in the range of α Pavonis. This is an error

of 25% and probably a good deal larger than the percentage error which may exist in the other systems, which all show a greater range, and most of which, being fainter stars, are much better provided with suitable comparison stars. In making Argelander comparisons steps as small as 0.03 or even 0.02 magnitude are often used and probably purely observational errors are smaller than these steps. We cannot speak of "probable errors" as the magnitude observations are few. As the determination of colours itself demands concentration, it is advisable to keep determinations of magnitude entirely separate from colour measures, except for the use of predictions derived from the colour epochs.

It is probable that the conclusions reached in this final table are fairly reliable and supply for the first time an acceptable picture of the normal companion star of the typical true "single-lined" spectroscopic binary.

The picture of the primary in such a system, usually of type B, is almost equally interesting. It appears to be a type A giant, and it may be asked whether the ionization of helium shown in the normal spectrum is not due to radiation from the secondary. If so it may be expected to vary during the revolution of the companion and disappear during the total eclipse.

The precise information latent in more accurate measurement of small magnitude variations discovered through colour variations is surely made very obvious here.

TOTALLY ECLIPSING COLOUR VARIABLES—COLOUR INDICES, MAGNITUDES, AND DIMENSIONS

Star	m	Range p	mag.	I_0	M	I	R	(Sun = 1.0) W	D	Mass Ratio
Lambda Eri. B2′	4.34	.006	0.18	—0.29	—1.59 +0.26	+0.05 —1.27	7.4 0.26	6.7 3.33	0.02 200	0.50
Beta Ori. B8p′	0.34	.004	0.06	—0.22	—6.59 —3.55	—0.06 —1.47	60 1.0	92 18.8	.0004 20	0.20[1]
Tau Ori. B5′	3.68	.011	0.22	—0.19	—0.89 +0.75	+0.04 —0.87	5.3 0.44	5.0 2.8	0.03 30	0.56
Delta Ori. B0′	2.48	.006	0.10	—0.34	—3.53 —0.98	—0.12 —1.51	13 0.29	18.7 5.2	.008 200	0.28[2]
Mu Ori. A2′	4.3	.027	0.08	+0.13	+1.54 +4.39	+0.34 —0.86	3.0 .084	2.24 1.09	0.1 2,000	0.49[3]
Theta Car. B0′	3.03	.007	0.05	—0.34	—2.69 +0.65	+0.04 —2.50	12 .021	11.4 2.9	.007 300,000	0.25[4]
Theta 2 Cru. B3′	4.98	.005	0.08	—0.25	—1.44 +1.36	—0.03 —1.59	5.9 .086	6.4 2.35	0.03 4,000	0.37[5]
Rho Cen. B3	4.20	.015	0.13	—0.34	+0.21 +2.45	—0.13 —1.28	2.3 .093	3.38 1.74	0.3 2,000	0.51
Delta Lib. A0′	4.83	.016	1.10	+0.04	+1.95 +1.34	+0.25 —0.07	2.1 1.5	1.97 2.35	0.2 0.7	0.84[6]

Star	m	p	Range mag.	I_e	M	I	R	(Sun = 1.0) W	D	Mass Ratio
Lambda Oph. A0′	4.0	.021	0.10	—0.08	+0.71 +3.27	+0.06 —0.97	2.6 0.11	2.82 1.43	0.2 1,000	0.51[7]
Alpha Pav. B3′	2.12	.014	0.04	—0.32	—2.11 +1.40	—0.10 —2.19	7.1 0.027	8.4 2.32	0.02 100,000	0.28

REMARKS

[1] Brightest known ecl. var.; [2] Recognized abroad as ecl. var.; [3] Vis. bin., corrected; [4] Densest companion in list; [5] Var. confirmed by 5 witnesses; [6] Typical Algolid; [7] Vis. bin. corrected.

The typical Algolid δ Librae contrasts sharply with the other ten systems, the mass ration of which averages 0.4 (*cf. LOB* no. 355, *Berlin-Babelsberg* B 5, H 6, *MNRAS* 88, 695). The visual binaries are corrected assuming the visual companion to be of the type indicated by the Russell Diagram, and colour equivalent according to Kukarkin. About as many more systems are now under observation and the colour data for some are very extensive.

The Intensity of Illumination of the Colour Scale (Appendix A)

The intensity required at the colour scale must be rather low, otherwise the image produced on the observer's retina is liable to persist long enough to influence the measurement. It should be possible with entire comfort to glance very quickly at the stellar image and the scale colours alternately. On the other hand the use of too low intensity in the images causes the colours to become greyish and to lack the vividness required for accurate comparison.

Electric lamps vary in efficiency, according to the type of bulb used, *e.g.*, clear glass, frosted, and blue bulbs (*e.g.*, "daylight lamps"). For stellar work the ordinary clear glass and frosted bulbs should be used exclusively, but the employment of daylight lamps is touched on below.

The following examples illustrate the use of various lamps employed in Wellington. An indication of the intensity of illumination obtainable is given by the power of the lamp in watts, and the distance from the lamp to the scale along the path of the light (deflected if necessary by a mirror). If we divide the power in watts by the square of the distance in feet, we obtain a value which, multiplied by a factor representing the efficiency of the lamp, gives us the intensity of the illumination.

At the writer's home station a clear glass bulb of 50 watts is employed in a large basement. A beam through a clear window may be used with the scale at a distance of 24 to 30 feet. Here the square of the distance ranges from 576 to 9000 square feet, and so the intensity (taking efficiency as 1.0) becomes 0.09 to 0.06. This is a very comfortable intensity, reducible if necessary by inclining the scale. However the beam passing through the door of the basement in an easterly direction leads at a distance of 45 feet to a site generally more suitable,

since less of the sky is obscured by the house and a hill to the west. Here the square of the distance is 2025 and the intensity becomes 0.025. This is the weakest value desirable, but it permits observation of rather faint stars.

At the Wellington Royal Society's Observatory in Kelburn, frosted bulbs are used, the principal one being of power 75 watts, and the other, 8 feet more distant from the scale, 60 watts. The former bulb is generally used alone and its distance via the mirror to the scale varies from 21 to 27 feet. This gives a comfortable illumination and since the power divided by the square of the distance gives values ranging from 0.17 to 0.10, the efficiency of the frosted bulb appears to be about half that of the clear bulb used at home. If the second bulb is used and its intensity added, we obtain for our illumination, 0.12 to 0.08. This intensity is ample but not excessive. (We have allowed for efficiency 0.5.)

Another frosted bulb, used at the writer's home for the inter-comparison of scales, has a power of 100 watts and is used at a distance of 19 feet. The resulting intensity of 0.14 is rather excessive and tends to fatigue the retina. Latterly a shade has been added and the effective power of the lamp thus reduced by nearly one half.

A daylight blue lamp has been used at the Royal Society's Observatory exclusively for the observation of the planets, and intensities comparable with those suitable for stellar work are obtained at distances of 12 to 13 feet, the power being 100 watts. High magnifications (200 to 400) suitable for showing planetary details were used. The dividends 0.69 and 0.59 thus obtained are suitable for the outer planets Mars, Jupiter, and Saturn and seem to indicate that the efficiency of such a lamp is only about 0.12 of that of a clear bulb. For such an extremely bright object as the planet Venus it was necessary to make the distance only 3 feet, whence the dividend became about 11.

The equation for the intensity of illumination may be given as:

$I = EW/D^2$, where W = power in watts; D = distance in ft.; E = efficiency factor, 1.0 for clear bulbs, 0.5 for frosted, and 0.12 for daylight blue.

From an examination of the site of the City Observatory, Wellington, it appears that a light path of 31 feet was used and a 100 watt lamp, for which the above formula would give $I = 0.05$, the bulb being frosted. A lamp of this power was used for a time but was replaced by one of 150 watts, if the writer remembers rightly.

Observers should find that as a result of applying the above formula, the intensity I will give good results if it lies between 0.025 and 0.12.

Correlations of Uniform Colour with Colour Indices and Equivalents (Appendix B)

As the Uniform Scale was purposely designed to conform to a linear relation between colour indices and itself, a close correlation has always been maintained. The indices quoted by Russell, Dugan, and Stewart

(extended where necessary by interpolation, Vol. 2, p. 734) covered some thirty spectral types and were used annually for correlation until 1937, when the regression equations used at present were obtained. The correlation was carried out by the method which may be found in any work on Statistics. A similar correlation with a smaller number of types for which the indices were given by Ludendorff (Newcombe-Engelmanns *Populäre Astronomie,* p. 552) gave a correlation coefficient of +0.94, but Russell, Dugan, and Stewart's types gave a closer correlation, coefficient +0.996.

The regression equation was:

$$I = 0.372C - 2.71, \text{ or } C = 2.69I + 7.28.$$

In 1937 we received Kukarkin's valuable publication (*Publications of the Sternberg State Astronomical Institute,* Vol. X, pt. 2) which is a catalogue of colour equivalents of stars derived from world-wide sources. Towards this work we had contributed our First Colour Index Report (1934) and when the publication reached us about 300 stars occurring in the catalogue had also been measured here. The colour equivalent of a star, following Hertzsprung, is defined by dividing the surface temperature of the star in degrees absolute into the constant 14,600. The regression equations obtained from the close correlation found for the 300 stars were:

$$E = 0.692C - 4.10, \text{ and } C = 1.444E + 5.92.$$

It will be readily seen that in these equations, enabling us to convert colour equivalents or colour indices into uniform colours or vice versa, C is always found by multiplying I or E by a factor greater than 1.0, hence an error of 0.01 in I or E is also increased in the conversion into C. That is why the Sternberg Colour Equivalents do not give Uniform Colour values which are quite as accurate in the second decimal place as are the orignal equivalents. Of the three scales, that of Uniform Colours is the most finely graduated, just as centimetres are finer graduations than inches, so that an error of 0.1 inch becomes about 0.25 cm.

Correction of Colour Epochs to Opposition of the Variable (Appendix C)

The fact that light takes an appreciable time to traverse astronomical distances was first realized by Römer in connection with the eclipses of Jupiter's satellites. The time taken to traverse unit distance (*i.e.*, the mean radius of the Earth's orbit around the Sun) is given by the British Astronomical Association's Handbook as 8.306 minutes or 0.005768 day. Since our colour curves are plotted in Julian Days and decimals, the latter figure is most suitable for this discussion. Reduction of observations to the time of arrival of the light at the Sun would involve changes of sign and so introduce a complication absent from the

method of reduction to opposition of the star. If we consider a colour variable in the plane of the ecliptic, the shortest time in which a colour change could reach us would occur at the time of opposition of the star. This time is found by ascertaining the longitude of the star from a celestial globe and also the date at which the Sun's longitude is 180° different from that of the star. We know for instance that the Sun's longitude is about 0° on March 22 and that it increases 90° for every 91 days or three months. For our purpose it suffices to measure longitudes to the nearest degree only. Now on a date differing from that of the star's opposition, the angle λ indicates the difference between the longitudes of the star and Sun, and its value in degrees is nearly the same as the interval in days from opposition. At $\lambda = 90°$ the star's light will have to travel as far as the Sun and will take 0.005768 day to do so. It will therefore bring us its signal so much the later as compared with opposition. The trigonometrical formula for this delay for any value of λ is $D = 0.0058\ (1 - \cos \lambda)$.

For stars not in the plane of the ecliptic, let ϕ = latitude of star. Then the complete "delay formula" is $D = 0.0058\ (1 - \cos \lambda)\ \cos \phi$.

For a given star this equation may be solved for one epoch each month and the values plotted as the "delay curve," from which the corrections to be subtracted from observed epochs or added to predicted epochs may be found for any date required.

A somewhat similar "delay effect" occurs in systems such as μ Orionis, *i.e.*, an eclipsing variable which is also a visual binary. In such cases the local delay effects may perhaps yield valuable information about the visual orbit.

WELLINGTON C2, NEW ZEALAND.

Marvelous Voyages—VII

ERRORS IN WELLS' THE WAR OF THE WORLDS

By LAURENCE J. LAFLEUR

1. It is not at all certain that Mars is older than the Earth.

2. The age is hardly important: life doesn't have a fixed rate of evolution.

3. There are no oceans on Mars.

4. The objections to a projectile fired from a gun as a means of interplanetary communication were considered in our treatment of Jules Verne's "From the Earth to the Moon." The acceleration to escape the gravitational field of Mars, while less than that of Earth, would crush all living things in the projectile, and probably the projectile as well.

5. If the projectiles travelled at a rate of many miles a second after leaving the immediate vicinity of Mars, the acceleration would be more

than necessary and the certainty of disaster still greater, if that were possible.

6. Unless the Martians have a very different kind of explosive, the gas formed would not be "chiefly hydrogen."

7. Wells appears to attach some importance to having all the shots fired at midnight exactly. But midnight at what meridian of the Earth? There would be some point if he had the projectiles *arrive* at midnight, precisely, since they come from Mars in opposition. Indeed, most of them arrive near this time.

8. If all the projectiles are fired from the same gun, the interval between shots will be not 24 hours, but the period of rotation of Mars, 24 hours, 37 minutes, 22.7 seconds, minus an allowance for the altered positions of the planets in their revolution about the Sun. This allowance should be 1 minute, 50.9 seconds, giving the proper interval between shots as 24 hours, 35 minutes, 31.8 seconds.

9. It seems unbelieveable that the Martians could control the projectiles so accurately as to make them all fall in England near London.

10. If they could choose an area, it would hardly be England. The center of a continental area is safest if they want to reach a land area; and an unpopulated region is safest as allowing time for them to consolidate their position.

11. If the projectiles encounter much atmospheric resistance, they would be consumed. If not, they would certainly fall with a million times the force needed to kill all passengers.

12. The energy of the fall would probably vaporize the cylinder, and would most certainly fuse the outer parts so that the cover could not be unscrewed from within.

13. Sand in the neighborhood would not be scattered: it would be fused at least, perhaps vaporized.

14. There would be a wind of hurricane force: *cf.* the Siberian meteor.

15. There would be a crater much larger than that described. The Meteor Crater of Arizona, four-fifths of a mile in diameter, is believed to have been produced by a meteor considerably smaller than one of the Martian cylinders.

16. The cylinder itself would probably be completely buried.

17. There would be no visible remnants of the tree on which it fell.

18. An unknown metal is highly improbable. An unknown alloy is plausible, but then the oxide would be recognizable.

19. The subjective appearance of a color is impossible to determine, even with animals we can handle in our laboratories. If a physiological meaning is to be read into the phrase, to say that blue and violet appear as black is equivalent to saying that the Martians do not see these sec-

tions of the spectrum.

20. Under the conditions of the high civilization postulated, it is more probable that the Martians would manufacture the blood for injection than that they would take it from other animals.

21. In any case different bloods clot when put together. How could the Martians rely on an unlimited variety of species? And how could they know that blood found on Earth would be suitable for their use?

22. Since sexual reproduction has arisen independently several times on Earth, it probably would do so on Mars, granted organisms as similar to ours as those described by Wells.

23. Under the circumstances, there could hardly be evidence of telepathy, even if telepathy itself is possible.

24. Wells probably means nitrogen when he refers to argon in the atmosphere.

25. Since the heat ray only softens iron, a steel mirror would seem to be at once a defence and a counter-attack.

26. Indeed, a glass mirror should be sufficient, since very little of the radiant heat would be absorbed.

27. From the description, the poison gas is not very potent: we know, and knew at the time Wells was writing, more deadly poisons.

28. An unknown element could not be present in the gas. The only elements unknown when Wells was writing were heavy elements whose compounds would not be gaseous.

29. Argon is inert. Wells again probably means nitrogen.

30. The gas could not act on the blood if it combines readily with water. It would combine with the moisture in the lungs, and might then kill by clogging them.

31. Artillery would be more effective against the Martian machines than Wells allows.

32. The surface of Venus is not yet readily accessible for telescopic observation. In any case it is difficult to see why the Martians should wish to produce simultaneous similar markings on Venus and on their native planet.

The Planets in September and October, 1943

By ALICE H. FARNSWORTH

NOTE: Greenwich Civil Time is used unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours; Central Standard Time, 6 hours, etc. War Time in each zone is one hour later than Standard. Phenomena are described as seen from latitude 45° N. *The American Ephemeris and Nautical Almanac* is the source of the data.

Sun. The Sun moves from a position in Leo (α 10^h $37^m.5$, δ $+8°$ $41'.2$) on September 1 into Virgo, where it crosses the autumnal equinox on September 23 at

22:12. It passes Spica October 16 and is still in Virgo when the month closes (α 14^h 21^{m}3, δ —14° 4′7 on November 1). Early in September the Earth reaches that portion of its orbit towards which the north end of the Sun's axis of rotation is inclined. As a consequence we see the sunspots, if any, carried across on paths slightly concave northwards.

Moon. Dates of phenomena are as follows:

		h	m
First Quarter	September	7	12 33
Full Moon		14	3 40
Last Quarter		21	7 6
New Moon		29	11 29
Runs low		9	9
In perigee		12	17
Runs high		22	8
In apogee		24	20
First Quarter	October	6	20 10
Full Moon		13	13 23
Last Quarter		21	1 42
New Moon		29	1 59
Runs low		6	16
In perigee		10	18
Runs high		19	16
In apogee		22	13

These Full Moons, adjacent to the autumnal equinox, are the Harvest and Hunter's Moons. The approximately Full Moon rises only slightly more than half an hour later on several successive nights. Autumn haze in the air is likely to deepen the ruddy color of the rising Moon and again the question will arise: "Why does the Moon look larger at the horizon than overhead?"

"The standard explanation has been that the Moon seems larger when seen in juxtaposition to distant objects on the horizon than when seen against the expanse of sky. Since the effect is the same for an unbroken horizon at sea as for a land horizon, this explanation is not satisfactory. Recent studies by Harvard psychologists show that the effect arises from a peculiar property of the brain and eye. When an object is seen directly ahead of the face, with the eyes set squarely in their sockets, it appears larger than when seen at angles above or below. If the observer is lying down, the Moon appears larger when overhead than when near the horizon."[1]

Aldebaran, Jupiter, and Regulus all lie at present in the direct path of the Moon. Consult the predictions for standard stations, page 391 for details.

Mercury crosses to the west side of the Sun on September 24. It passes half a degree north of β Virginis on October 7 and reaches greatest elongation west of the Sun on October 10. This is the best opportunity of the year to see the planet in the morning in the east, 60 to 30 minutes before sunrise. It would be interesting, three days later, to catch two planets in the same telescopic field (α 12^h 8^m, δ +1°.2): tiny, sun-baked Mercury appearing 37′ north of frozen Neptune, huge and distant. The fact that they will be too close to the Sun to observe need not prevent us from noting that the one, in quarter phase and a poor reflector, sends on sunlight which traverses the intervening space in less than 9 minutes; the other, a good reflector with its bright side towards us, is visible by means of sunlight which travelled outwards from the Sun for about 4 hours,

[1] Quoted from Whipple, "Earth, Moon, and Planets," page 101.

only to be caught and sent back another 4 light-hours to planet Earth, its intensity attenuated all the way by the inverse square law of radiation. Mercury ($-0^{M}.5$) would consequently appear 2500 times brighter than Neptune (8^{M}).

Venus on September 6 comes to inferior conjunction, passing by the Sun about 8° to the south of it. On the days before and after watch for the change from the eastward-pointing crescent to the westward-pointing crescent, as the rim of illumination slides from the west to the north to the east limb.

Thirty-six days later, on October 13, the planet reaches greatest brilliancy (stellar magnitude —4.3) west of the Sun, being then a waxing crescent resembling the 5-day-old Moon in shape.

Mars begins to come into view in the evening sky, rising an hour before midnight (War Time) on September 1 and four hours before by the end of October. Having passed rapidly through the constellations Pisces, Aries, and much of Taurus during the summer, the planet slows up as it approaches its stationary point. In its path just north of the Hyades in early September it will appear more than twice as bright as the ruddy star Aldebaran which it resembles in color. On October 28, having reached a point almost between β and ζ Tauri, and only 5° northwest of Saturn, it starts to move back westward through the stars of Taurus again (see chart in January issue, page 34).

Jupiter emerges sufficiently from the bright neighborhood of the Sun for the printing of its satellite phenomena in the *American Ephemeris* to be resumed after a hiatus of six weeks. It is available for telescopic observation before sunrise in the east, having moved through Cancer into Leo.

During these two months the Earth and Sun are crossing the plane of Jupiter's equator; this happens twice during a 12-year revolution of Jupiter around the Sun. Since the satellites move closely in this equatorial plane, now is the time to expect mutual eclipses and occultations of the satellites to be visible from the Earth. We have formerly been indebted to the Computing Section of the British Astronomical Association for predictions regarding these phenomena. "Unfortunately it was found to be impossible under present conditions to obtain the necessary data for the prediction of these phenomena. All that can be done, therefore, is to suggest that observers keep a look-out for these phenomena from September onwards."[2]

Saturn lingers near ζ Tauri throughout the fall months. It is at west quadrature on September 20. On October 9 it is stationary as if, having stepped up to the boundary of Orion, it decides to retreat westward. It is closest to Mars about the time when that planet turns westward (see chart in January issue, page 34).

At just this time when the orbits of Jupiter's satellites are seen most nearly edgewise the plane near which Saturn's satellites move is presented under its greatest width. As a consequence the brighter moons pass above or below the rings and ball at each conjunction.

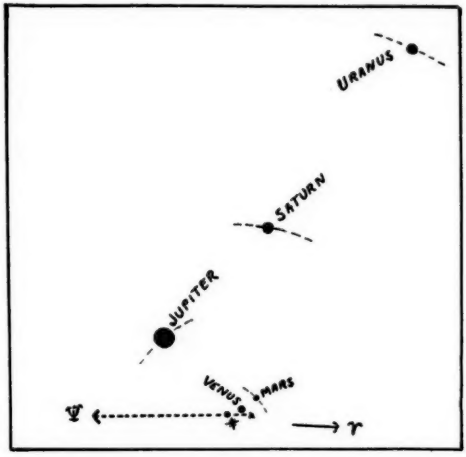
Uranus is the third planet in Taurus at the present time. It is 90° west of the Sun on September 2. Mars passes about a degree south of it on September 9 and Uranus itself starts moving westward on the 14th.

Neptune comes into conjunction with the Sun on September 25. On the morning of October 13 Mercury passes close to it. Having been north of the

[2] Quoted from the *Handbook of the British Astronomical Association*, 1943, page 3.

celestial equator since the beginning of the Civil War, it crosses in November to the south side. Early in the 21st century it will regain the position in Aquarius where it was discovered in 1846.

The chart shows the relative positions of the planets on the date when Mercury and Neptune are in conjunction west of the Sun in Virgo. Venus (at greatest



Planets in their relative positions on October 13, 1943. The dotted arrow leads from the Earth (x) through Mercury in the direction of Neptune, which should be 3⅞ inches away on this scale. The Sun is just below the line joining the Earth and Neptune.

brilliancy) and Jupiter lie in the direction of Leo; Mars, Saturn, and Uranus are grouped in Taurus.

Asteroid Notes

By HUGH S. RICE

During the period August 15 to October 15, there are 5 asteroids observable with a small telescope as follows: Iris, Pallas, and Vesta, which are the brightest, also Juno and Euterpe, which are not so bright.

7 Iris. On August 19 (0^h U.T.), Iris is 2° southwest of the star Alpha Aquarii; it is retrograding; the predicted photo-magnitude is 8.7; and the planet is becoming somewhat brighter. A plotting on a star atlas can be made from the ephemeris offered herewith. The stellar region traversed is interesting. On September 16 its position seems to be coincident with a 5th-magnitude star. It becomes stationary on October 4. There is a conjunction of Iris and Beta Aquarii on October 12.6 U.T., with Iris less than 4′ north of the star. On October 18 the planet is ½° east of Beta. [*Corrections:* In the June issue, p. 333, last line, and p. 334, second line, the star Gamma Aquarii is intended, not "α"; and on p. 334, top, the name *Juno* should read *Iris* in both cases.]

2 Pallas. On August 14 this minor planet is 3°.6 west and 0°.8 south of 60 Ceti; it is going direct but nearing its stationary point; its motion is approximately southward for several weeks; its predicted photo-magnitude is 10 and it is becoming brighter. On September 23 it passes by Zeta Ceti, being 1°.4 west of the star. On October 13 its position is 3° west of Tau Ceti, the predicted photo-magnitude being 9.1. Opposition is on October 17.

4 Vesta. Another apparition of this bright planetoid is beginning. Observers who wish to follow it for a long period should begin as soon as possible. The region of the sky traversed is interesting. Our ephemeris starts with Vesta immersed in the Hyades. On August 15.8 U.T. Vesta is in conjunction with Alpha Tauri, passing by at a distance of 19′ south of the star, on its course almost directly eastward. The photo-magnitude is about 9.8 but Vesta is orange or pinkish and is probably brighter in visual magnitude. It is becoming brighter, in fact, all the rest of the year. On August 18 it passes by Sigma-two Tauri, a little north of it, and on September 11 it is 1°.2 north of 11 Orionis. It does not begin to retrograde until after the middle of October. Opposition occurs on December 5.

3 Juno and 27 Euterpe. These asteroids are fainter than the others, and may be located by means of the ephemerides subjoined. The photo-magnitude of Juno is predicted as 10½ for August, and the planet is becoming slowly fainter. The photo-magnitude of Euterpe is given as 12 for mid-August; but it is becoming brighter, the magnitude for December 1 being 9.5. Opposition takes place December 7.

We are indebted to Dr. Dirk Brouwer of the Yale University Observatory for the ephemerides.

ASTEROID EPHEMERIDES FOR 0^h U.T. EQUINOX OF 1943.0

7 IRIS

1943	α h m	δ ° ′
Aug. 19	21 57.3	— 2 12
24	21 52.5	— 2 28
29	21 47.7	— 2 47
Sept. 3	21 43.0	— 3 9
8	21 38.7	— 3 32
13	21 34.9	— 3 56
18	21 31.8	— 4 20
23	21 29.4	— 4 42
28	21 27.9	— 5 2
Oct. 3	21 27.3	— 5 20
8	21 27.5	— 5 35
13	21 28.7	— 5 46
18	21 30.7	— 5 54

2 PALLAS

1943	α h m	δ ° ′
Aug. 14	1 45.9	— 0 51
19	1 47.5	— 1 45
24	1 48.6	— 2 46
29	1 49.1	— 3 51
Sept. 3	1 49.0	— 5 2
8	1 48.4	— 6 18
13	1 47.3	— 7 38
18	1 45.5	— 9 2
23	1 43.2	—10 27
28	1 40.5	—11 53
Oct. 3	1 37.2	—13 18
8	1 33.7	—14 42
13	1 29.9	—16 1

4 VESTA

1943	α h m	δ ° ′
Aug. 9	4 23.9	+15 50
19	4 36.7	+16 11
29	4 48.3	+16 25
Sept. 8	4 58.4	+16 34
18	5 6.8	+16 37
28	5 13.2	+16 36
Oct. 8	5 17.0	+16 32
18	5 18.2	+16 27

3 JUNO

1943	α h m	δ ° ′
Aug. 19	18 57.2	— 8 1
29	18 54.1	— 9 7
Sept. 8	18 53.6	—10 11
18	18 55.7	—11 10
28	19 0.1	—12 3
Oct. 8	19 6.7	—12 49
18	19 15.5	—13 26
28	19 26.0	—13 54

27 EUTERPE

1943	α h m	δ ° ′
Aug. 14	3 53.5	+18 46
24	4 10.1	+19 31
Sept. 3	4 25.8	+20 8
13	4 40.2	+20 36
23	4 52.8	+20 57
Oct. 3	5 3.3	+21 12
13	5 11.0	+21 22
23	5 15.5	+21 28

Hayden Planetarium, American Museum of Natural History, New York, N. Y., July 24, 1943.

Occultation Predictions for September and October, 1943

(Taken from the *American Ephemeris*)

Date 1943	Star	Mag.	IMMERSION Greenwich C.T.	*a*	*b*	Angle E from N	EMERSION Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
	OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′									
Sept. 9	21 Sgr	5.0	1 12.1	..	..	24	1 45.9	..	..	334
11	o Cap	6.1	1 35.2	..	..	7	2 1.2	..	..	329
18	B.D.+11°445	5.9	3 19.6	..	..	3	3 45.1	..	..	314
19	179 B.Tau	6.0	5 7.8	—1.0	+1.3	94	6 11.8	—0.7	+2.3	225
25	227 B.Cnc	6.5	9 28.1	—0.7	+1.8	81	10 38.7	—1.3	+0.1	298
Oct. 7	π Sgr	3.0	1 35.4	—2.1	—2.7	137	2 14.9	—0.1	+1.0	205
8	θ Cap	4.2	23 12.7	—1.5	+2.2	27	0 4.7	—2.2	—0.7	305
8	B.D.—18°5862	6.0	23 54.5	—2.0	+0.2	100	1 4.5	—1.5	+0.9	227
9	ι Aqr	4.4	23 46.8	—1.6	+1.2	69	1 3.4	—1.7	+0.7	251
10	42 Aqr	5.6	5 47.8	—0.6	—0.8	76	6 47.0	—0.2	—0.4	240
15	μ Cet	4.4	1 39.4	+0.2	+3.2	10	2 15.0	—1.5	+0.2	303
17	264 B.Tau	4.8	0 51.7	—0.2	—0.4	140	1 13.1	+0.9	+3.3	188
23	Jupiter	—1.5	..	..	..	..	5 45.0	..	..	347
	OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′									
Sept. 6	γ Lib	4.0	1 31.3	—1.4	—1.1	94	2 43.6	—1.0	—1.8	293
9	21 Sgr	5.0	0 29.3	..	..	36	1 13.5	..	..	332
11	o Cap	6.1	0 57.7	..	..	13	1 24.7	..	..	332
11	υ Cap	5.3	6 15.0	—0.8	0.0	53	7 16.7	—0.9	—1.3	272
12	45 Cap	5.9	7 41.6	—0.5	+0.4	40	8 36.4	—0.8	—1.5	277
19	179 B.Tau	6.0	4 54.9	—0.2	+1.5	81	5 55.8	—0.4	+0.4	241
21	64 Ori	5.2	12 6.7	..	..	13	12 35.9	..	..	336
25	227 B.Cnc	6.5	9 18.6	0.0	+1.8	77	10 19.2	—0.7	+0.4	298
Oct. 7	π Sgr	3.0	1 0.1	—2.2	—1.3	124	2 1.0	—1.2	+0.6	223
8	θ Cap	4.2	22 39.0	—1.4	+2.5	36	23 30.6	—1.4	0.0	305
8	B.D.—18°5862	6.0	23 22.1	—1.5	+0.8	102	0 31.5	—1.7	+1.4	234
9	ι Aqr	4.4	23 19.3	—1.1	+1.6	71	0 30.0	—1.4	+1.2	258
10	42 Aqr	5.6	5 32.5	—1.1	—0.1	61	6 39.8	—0.8	—0.6	250
15	μ Cet	4.4	1 43.4	..	..	343	1 48.0	..	..	335
17	α Tau	1.1	3 13.2	..	..	143	3 32.4	..	..	183
18	119 Tau	4.7	4 36.8	—1.1	—0.4	135	5 9.6	+0.6	+3.7	198
23	α Leo	1.3	19 52.9	+0.6	—3.1	168	20 22.6	—0.2	—0.1	230
	OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′									
Sept. 9	108 B.Sgr	6.5	5 10.5	—1.9	—1.1	108	6 20.9	—1.1	—0.2	243
11	υ Cap	5.3	5 40.3	—1.3	+2.0	25	6 33.2	—2.7	—1.8	303
12	45 Cap	5.9	7 23.9	..	..	358	7 51.3	..	..	317
17	ξ^2 Cet	4.3	7 44.5	—1.7	+1.0	95	8 47.4	—0.9	+2.6	210
18	8 B.Tau	6.2	9 40.0	—2.9	—0.7	117	10 30.1	—0.5	+4.1	192
Oct. 6	μ Sgr	4.0	2 48.5	..	..	158	3 17.9	..	..	200
6	15 Sgr	5.4	3 16.8	—1.6	—0.3	73	4 31.1	—1.4	—1.4	282
7	π Sgr	3.0	0 7.4	—1.4	—0.9	138	1 3.2	—2.3	+1.9	225
8	σ Cap	5.5	5 24.9	—1.3	—0.1	64	6 35.7	—1.1	—0.9	263
10	42 Aqr	5.6	4 52.3	—1.3	+1.8	30	5 57.6	—2.5	—0.8	281
21	d^1 Cnc	5.9	13 17.4	—2.6	+1.6	72	14 40.7	—2.1	—2.4	312

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly,

with the latitude, using b; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

IN MEMORIAM.—The sad news has been transmitted to me through another member of the Society, who had seen the casualty list issued by the War Department published in a Chicago paper that William A. Borden, U.S.A., of Birmingham, Michigan, had been killed in action in the Aleutians. In the untimely death of this young soldier our Society has lost one of its very best and most active members. Beginning his work with us in 1940, he plotted 353 meteors on 16 nights. This rose to 1256 meteors on 34 nights in 1941, thus breaking the year's record for the A.M.S. Entering service early in 1942 his interest did not lessen and, despite all the strenuous military duties during training, he was still able to send in 44 observations from camp. His letters to me, while in training, showed a fine patriotism and a cheerful determination to do his full duty. Now he has been called to make the supreme sacrifice, perhaps in his first battle. May he be an example to all his fellow members to serve their country equally well! On behalf of our Society, I extend to his mother and other members of his family our sincerest and deepest sympathy.

Before these Notes appear it is probable that the Perseid maximum will have passed. As it comes when there will be little interference from moonlight we hope for good results. The absence of so many of our best observers in the armed forces perforce cuts down the work of our Society in 1943 very greatly. Therefore those whose time is not too occupied with the war effort might try a little harder to make up for these losses. We have been fortunate recently in receiving a large number of reports on a Texas fireball of June 16 and one seen from an area with New York City about center on June 21. As the first left a smoke train visible for from 10 to 20 minutes, more observations are urgently desired. I have finished the computations on several fireballs lately and others are being completed under my supervision. The number of incompleted ones is being steadily reduced. But reductions of other meteoric data have to be temporarily laid aside, to a considerable extent, due to the lack of staff assistance. Reports on three fireballs follow.

FIREBALL OF 1932 JANUARY 10

EDITH F. REILLY

This celestial object made its appearance about 9:28.5 P.M., C.S.T., on the above date. Its path was from the southwestern part of Illinois to southern Missouri, passing overhead at St. Louis.

Through the efforts of Wesley Simpson, of Webster Groves, Mo., the local regional director for the A.M.S., Flower Observatory received 47 reports on this object, of which 33 were used to determine the beginning point and 32 for the end. Someone at Flower Observatory had done a little preliminary work on this fireball, but finding that about half of the observations were from St. Louis and

Webster Groves, whose distance apart is six miles only, he did not finish it. I noticed that the rest of the observations were fairly well scattered and attempted a solution. The beginning point was difficult to determine because observations were lacking from stations well to the side of the path, but those for the end were from stations more favorably located.

Although most of the reports state that it did not explode, Harvey Sheldon, Hooker, Missouri, S1, stated that it did. S1 is the nearest station to the determined end point, being only 48 km distant. He also said that he heard it and that it "sounded like a heavy muffled blast." Wesley Simpson said "it threw off streams of sparks." This fireball had a green nucleus with a red cap which lasted about 5 or 6 seconds. It was accompanied by a train which was green at the center with a red edge and remained visible for 4 or 5 seconds. From the majority of the reports, we gather that it was at most 5/6 the size of the Moon or at least 4 or 5 times the apparent diameter of Venus. Most reports agreed that it was brighter than the Moon and, from those that made numerical estimates, it seemed to be three times as bright, brilliant enough indeed for objects on the landscape to be visible. Opinion was divided as to whether it expanded or not, but quoting Wesley Simpson, "it appeared to grow larger as it progressed (slightly)." Its shape was elliptical.

With Dr. C. P. Olivier acting as adviser, the solution gave the following data:

Date	1932, Jan. 10, 9:28, 5 P.M., C.S.T.
Sidereal time at the end point	70°
Began over	$\lambda = 89° 20'$ W; $\phi = 38° 56'$ N, at 92 ± 24 km.
Ended over	$\lambda = 91° 42'$ W; $\phi = 38° 09'$ N, at 15 ± 13 km.
Length of path	231 km.
Projected length of path	218 km.
Duration	5.5 sec.
Observed velocity	42 km/sec (very uncertain).
Radiant (uncorrected)	$a = 246°$; $h = 18° 21'$; $\alpha = 160°$; $\delta = +30°$.

This radiant was not corrected for zenith attraction, as the position derived cannot be very accurate and the correction, in any case, is of the order of 1°.

Due to the very low height of the ending point, it seems quite probable that meteorites may have fallen. However, the determination of the geographical coordinates of the end point is not sufficiently exact to make a search for such fragment profitable.

Daylight Fireball of 1934 December 2*

By Sterling Bunch and C. P. Olivier

On this date at 4:07 in the afternoon a remarkable fireball started over the eastern border of Tennessee and, following a course towards the southwest, ended over northern Alabama. The task of gathering data in the region was assigned to Sterling Bunch, then regional director for the A.M.S. in Tennessee, and to P. O. Parker then regional director for Georgia. This was accomplished through the press, letters, and interviews, in all about 25 reports being made available. In several cases other A.M.S. members interviewed eyewitnesses and measured the angles pointed out, to the great good of the resulting data. In due time Bunch made a full solution of the atmospheric path and wrote a preliminary article,

*To my great regret, no word of approval of this article has been received from Mr. Bunch, though a copy was sent to him some weeks ago. I therefore am taking the liberty of leaving his name thereon, without his approbation, as the part accredited to him is substantially as found in his original paper. C.P.O.

which was sent to headquarters here. The data were then partly checked by Olivier, and the article, through some inexplicable mistake, laid aside and overlooked in the mass of unsolved fireballs. For the resulting delay Bunch has no responsibility as he had promptly done his full part. However, the papers were recently unearthed at Flower Observatory and the solution completely checked by Olivier. The only data which this later study modifies are the beginning height (originally marked uncertain) and the resulting slope. The new value gives 60 km instead of 66 km with the slope at the mid-point 3°.5 instead of 4°.5. As the path is so long, this changes the position of the radiant very little. The data given hence are practically the same, on the whole, as those originally calculated by Bunch, and Olivier's part in the solution was merely that of checking it quite thoroughly and computing the orbit.

The end point's height appears well determined; if all 14 values are used we get 40.2 ± 15.6 km, if the two most discordant values are omitted we get 40.7 ± 12.7 km. The height of the beginning point is much more difficult to evaluate accurately. The 3 best observations, which appear to belong to the actual beginning point, would give 77 km. But when we use the 9 others distributed along the path and then take the slope which best fits all 12, we are forced down to about 60 km. The true height is perhaps slightly greater, but in any case the path was not far from horizontal. When zenith attraction is allowed for, the radiant seems to have been actually below the horizon. As the fireball disappeared at a height of 40 km, it is very improbable that any fragments fell as meteorites. The body, seen as it was in full sunlight, was evidently large and bright. It was described as oval-shaped, blunted in front and tapering out to a point behind. Many said it was "brighter than full Moon," others that it was "about size of quarter Moon." The color was white to greenish; out of 16 who noted it only one said orange, one blue to fiery red. That 14 out of 16 almost agree is unusual and indicates that the color was striking. No long-enduring train was left, 4 and 5 seconds are the only two definite estimates of the duration of the train. Nine report the number of seconds that the fireball itself was visible; as some of these undoubtedly saw only part of the path the average estimate of 6.94 ± 2.77 sec. is considered an underestimate. The general statement made by others that it moved slowly fortifies the opinion just expressed. It did not explode. As usual, it gave the impression to many people that it was not far from the ground, or would strike at a point close by—both illusions!

Date	1934 Dec. 2, 4:07 P.M., C.S.T.
Sidereal time at end point	316°.2
Began over	$\lambda = 83°\ 18'$ W; $\phi = 35°\ 42'$ N, at 60 km.
Ended over	$\lambda = 86°\ 22'$ W; $\phi = 34°\ 12'$ N, at 40.2 ± 15.6 km.
Length of path	325 km
Projected length of path	324 km
Velocity	47 km/sec (very uncertain)
Radiant as seen from end point (uncorrected)	$a = 239°$; $h = 2°.0$
Zenith correction (heliocentric parabolic velocity assumed)	—4°.2
Radiant (corrected)	$a = 239°$; $h = -2°.2$; $\alpha = 66°$; $\delta = +24°$

When some allowance is made for the possible errors in position of the radiant, the one just derived is near enough to those of the Taurid stream, calu-

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lated by Whipple* from Harvard photographs, to make the orbit worth computing. With what is given above and longitude of meteoric apex = 159°.2, and coordinates for the radiant $\lambda = 69°$, $\beta = 2°$, two orbits were derived. (A) assumes heliocentric parabolic velocity; (B) assumes that the fireball had an orbit with the same major axis as Encke's Comet, *i.e.*, 2.217. The same zenith correction was, however, used in (B) as the change would have been slight in any case and the data too rough to justify great precision.

	(A)	(B)	Encke's Comet
a	∞	2.217	2.217
e	1.00	0.73	0.85
q	0.51	0.60	0.33
ι	2°	2°	13°
Ω	70°	70°	335°
ω	85°	86°	184°
π	158°	155°	159°

Neither set of elements agrees very well with those of Encke's Comet. However, Whipple in the article mentioned has shown what great perturbations members of the Taurid stream suffer, so that we may still believe that there is a strong possibility that this fireball may have been a member. Incidentally, were the radiant we have derived shifted in the right direction only a very few degrees, a much closer agreement would be had.

Fireball of 1933 November 17

On the afternoon of this date at about 5:07 P.S.T., a conspicuous fireball appeared over central Washington and, moving in a general southwest direction, ended near the west coast in Oregon. Our very efficient regional director, Prof. J. Hugh Pruett of the University of Oregon, undertook the gathering of data through requests in the local papers, correspondence, etc. As a result he was soon able to publish in several papers in his territory a map showing the approximate path of the meteor, giving at the same time a full general discussion of the accompanying phenomena. Shortly thereafter, the data were all sent to A.M.S. headquarters and preliminary work done here. As so often happens, the papers were laid aside and only recently resurrected. I handed them over to Miss Edith Reilly, graduate student in Astronomy, and she completely checked all that had been done here and made a new map showing the azimuth lines. She also made a first approximation for the beginning height but, inspection showing that it was a particularly difficult case, I took it over and finished it. The work of both persons mentioned greatly simplified my own and I desire to express due appreciation to them.

Actually, I replotted the azimuth lines on a larger-scale map, and restudied the observations trying to find one or more made by a trained observer and which would serve as a cornerstone, so to speak. In this I was unsuccessful, since the fireball was seen in full daylight and there were no reference points in the sky. Even some azimuths were under suspicion as to whether persons who used a compass had applied the rather large local correction to true north. Also the altitudes, in cases, might have been seriously influenced from the mountainous character of the region, making the apparent very different from the true horizon. However after several approximations the results which follow were obtained. Frankly, it was impossible to reconcile all the observations, so 3 for beginning height and 4 for end height were rejected for no other reason than that they disagreed very greatly from the mean of the others, 6 being grossly too large, one

impossibly small. Using the others, fairly satisfactory results were derived, yet not so good as had been hoped for from a preliminary inspection of the data. Also the adopted path was checked by heights at 5 points which were near the middle of the path. Four out of the 5 agree well with the slope given, and hence add confidence to the adopted heights. The duration of flight based upon 10 estimates is 5.30 ± 1.60 seconds. This estimate is probably too small. There is great unanimity in the color, described as blue by most, green or white being used or added by others. The description of size varied from three times that of Venus to that of the Moon. It seems pretty certainly to have presented an apparent disc. At the end it broke into pieces, the observer at Ilwaco, S7, saying that he heard the "explosion" instantly and that "trail of white light 24 to 30 feet long flaming out behind the meteor" was seen. The simultaneous "hissing" was heard as the meteor passed over certain people. Others did not hear the explosion though as near the end point as was S7, which incidentally is calculated to be 61 km away though they thought it very near! Despite its large size, the considerable final height of 50 km makes it most improbable that debris reached the ground. This height varies considerably from the (approximate) one of "close to 20 miles," *i.e.*, 36 km, given by Pruett in the papers. But he used only a few observations in deriving this value which do not seem to me superior to the others. Also his solution was admittedly preliminary. Some newspaper reporters without consulting Pruett on the subject took on themselves to say that the object was "a straggler" from the Leonid shower, which was then at maximum. This is obviously absurd as the radiant was about 100° from that of the Leonids! The data follow.

Date	1933 Nov. 17/18, 5:07 P.M., P.S.T.
Sidereal time at end point	309°.7
Began over	λ 121° 08′, ϕ 47° 18′ N at 118 ± 25 km (5)
Ended over	λ 123° 42′, ϕ 45° 45′ N at 50 ± 22 km (10)
Length of path	268 km
Projected length of path	259 km
Velocity (observed)	50 km/sec (very uncertain)
Radiant as seen from end point (uncorrected)	$a = 238°$, $h = 13°.4$
Zenith correction (heliocentric parabolic velocity assumed)	$-2°.8$
Radiant (corrected)	$a = 238°$, $h = 10°.6$; $\alpha = 56°$, $\delta = +30°$; $\lambda = 61°$, $\beta = +10°$

It so happens that work on this fireball was completed after that on the one forming the first part of these Notes. At once certain similarities struck me and, as a result, a parabolic orbit (A) and an elliptical orbit (B) have been computed for it, the same assumptions being made in the latter orbit as were for (B) orbit of the other fireball. The results follow.

	(A)	(B)	Encke's Comet
a	∞	2.217	2.217
e	1.00	0.78	0.85
q	0.52	0.49	0.33
ι	10°	8°	13°
☊	55°	55°	335°
ω	86°	98°	184°
π	141°	154°	159°

The remarks on the orbit of the other fireball apply equally here and the agreement with the comet's orbit is considerably better. The appearance and

behavior of the two bodies seem very similar. Hence there is no hesitation in suggesting rather strongly that both of these fireballs belong to the Taurid stream and we know that this, as was proved by Whipple, is connected with Encke's Comet.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pennsylvania, 1943 July 24.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
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Concerning Possible Lunar Meteoric Phenomena

By WALTER H. HAAS
Department of Mathematics, Ohio State University, Columbus
(Communicated by Lincoln La Paz)

ABSTRACT

This paper contains an account of two possible *lunar meteors* recently observed by the author and Mr. R. G. Johnson. Data concerning systematic searches for lunar meteors undertaken in the course of the years 1941-43 also are given. The importance of continuing such systematic searches is emphasized.

Recently L. La Paz[1] has published two sets of calculations (the first based on empirical data, the second on theoretical considerations), both of which indicate that if meteorites weighing 10 pounds or more impinged *directly* on the surface of an airless Moon, the resulting impact-flares would be bright enough to be readily visible on the Earth. He inferred from the absence of observations of such meteoritic impact-flares that a rare lunar atmosphere exists and called attention to results long ago secured by W. H. Pickering (and, apparently independently, by A. C. D. Crommelin), which give a satisfactory explanation of the efficacy of such a tenuous atmosphere as a shield against meteoritic bombardment.

One implication of the existence of a lunar atmosphere is that *lunar meteors* must occur within it. No references to the observation of such meteors are found in the literature of meteoritics. However, the fact that observations made by persons *not looking carefully for lunar meteoric phenomena* have not revealed any cannot be regarded as *conclusive* proof of their non-existence. One could on equally good (but quite misleading) observational evidence infer the absence of the Crape Ring of Saturn, prior to 1850![2]

A simple calculation shows that the most brilliant lunar meteors could be observed telescopically from the Earth as faint specks of light moving short distances across the surface of the Moon during their brief periods of visibility.[3] It was, therefore, with very considerable interest that I perceived just such a

phenomenon and that I learned later of a similar observation made by Mr. Robert G. Johnson of Le Grand, Iowa. The basic data on these moving lunar specks follow:

Observer	Johnson	Haas
Date	August 24, 1942	July 10, 1941
Time	$3^h\,36^m$, U. T.	$5^h\,44^m$, U. T.
Telescope	8-inch reflector	6-inch reflector
Moon's Geocentric Right Ascension	307°	305°
Moon's Geocentric Declination	—15°	—17°
Age of Moon	12^d	16^d
Conditions of Observation	Fairly good	Rather poor
Lunar Longitude of Path of Speck	+44°	—38°
Lunar Latitude of Path of Speck	+47°	—18°
Lunar Direction of Motion	Northward	Eastward
Length of Path	18 miles	63 miles
Apparent Stellar Magnitude of Speck	+4?	+8?
Duration of Visibility	$0^s.25 - 0^s.33$	$1^s.0$?
Apparent Angular Diameter	$0''.5 - 1''.0$?	$< 0''.5$?

The last three items are very uncertain. The angular diameters were *completely inappreciable*, but the upper limit of 0".1, which I previously suggested for my speck,[3] may well be much too small. The lengths of the projected paths are probably not in error by as much as 20%; they were determined by measuring a lunar photograph and a tracing of a drawing of a crater.

In seeking to explain such surprising appearances, one must bear in mind the possibility of illusion. It is known that visual meteor observers are sometimes deceived by false meteors originating in their eyes.[4] Certainly it would be of interest to have the opinion of an expert on the illusions of vision as to whether our moving specks could have been false effects of some kind. In writing to me about such a possible explanation of his own speck, Johnson emphasized the distinctness with which he had seen it and described how it differed from illusions that he had noticed. As for my own speck, I saw it so plainly that I cannot conceive of its having been unreal; then, too, if illusion was the cause, I should have seen other moving lunar specks in the course of the roughly 1,500 hours that I have spent in visual studies of the Moon.

One next inquires about terrestrial objects low in the atmosphere as a possible explanation. The speck which I *suspected* at $5^h\,41^m$ on July 10, 1941,[3] does suggest a repeating cause of this kind, but it was seen so poorly that no valid conclusions can be based upon it. One must not forget that the two well-seen specks did not possibly cross the whole telescopic field of view and that they appeared *bright* against the Moon. Moving *dark* objects seen against the Moon are not uncommon phenomena for an attentive telescopic observer; these are, at least chiefly, insects and birds. It is true that a flying illuminating insect, such as a firefly, could have a short apparent path and could appear bright against the Moon. However, if a firefly were remote enough for its luminous apparatus to be less than 1" in angular diameter, its apparent stellar magnitude would be less than that of the specks, as can be shown by computation.

We consider next terrestrial meteors very close to their radiants. It would be of some value to search through published lists for radiants so located in space and time as to be capable of giving rise to our specks, but since there can be no doubt that many of the published meteoric radiants are spurious and that many true radiants are still undiscovered,[4,5] such a search could not establish a certain conclusion. To be sure, it is of interest that each speck was seen with the

Moon near the point whose coördinates are $\alpha = 306°$, $\delta = -16°$. To the best of my knowledge, our two observations are unique in lunar literature; it is evidently very difficult to perceive telescopically a meteor projected against the Moon. That *two* observations of such great rarity should fall so close together in time would be very curious.

We appear to be justified, then, in considering the possibility already stated, namely that these moving specks were due to luminous meteorites in flight in the lunar atmosphere. One would then obtain as the stellar magnitudes at a distance of 100 miles, *about* —13 for Johnson's object and —9 for mine, values comparable to those of the more brilliant terrestrial fireballs. The *minimum possible selenocentric velocities* come out to be, but with *great* uncertainty, 54 to 72 miles/second for Johnson's speck and 63 miles/second for mine. The *heliocentric* velocities cannot be determined; however, the large values just given must be regarded as rather unfavorable to our hypothesis of lunar meteors. We must not forget, tho, that Hoffmeister and others have contended that still greater velocities occur in the case of terrestrial fireballs.[4] Angular diameters of as much as 1".0 for these specks would lead to linear diameters of at most 6,000 feet—not in excess of the *apparent* sizes of some terrestrial fireballs.[4]

It is not possible to test our hypothesis by searching for visible effects of the impact of our possible meteorites upon the lunar surface. Even the Canyon Diablo, Arizona, Meteorite Crater would not be recognized with *complete certainty* to be a new feature if it were suddenly transported to the Moon!

The *apparent* absence of previous records of moving lunar specks does not constitute decisive evidence against the reality of ours. Reliable observers are sometimes not anxious to publish extraordinary observations (I know personally of one such suppression of evidence), especially those which cannot be confirmed by other observers at future dates. Most amateurs publish nothing at all, and if any professionals have in the past heard of observations of moving lunar specks, it is rather probable that they did not credit them and hence did not publish them. Moreover, we must bear in mind the lack of *systematic* searches by *trained attentive* observers for possible lunar meteors. Prior to the searches listed in the following table, apparently the only *systematic* search for impact-flares or other luminous phenomena in the lunar atmosphere was the series of observations

Observer	Date (U.T.)	No. Minutes Observing	Size of Area Examined	Stellar Magnitude of Faintest Speck that could have been Seen
W. H. Haas	1941 August 17	40	200,000 mi.²	+10
"	August 18	16	120,000	+10
"	August 29	37	140,000	+10
"	October 17	12	400,000	+12
"	November 16	15	2,000,000	+14
H. W. Phillipps	1942 January 18	10	3,100,000	+ 6
"	January 22	20	2,300,000	+ 9
"	March 26	12	1,500,000	+ 5
W. H. Haas	May 18	13	3,500,000	+12
"	June 21	8	70,000	+ 8
"	June 22	12	290,000	+ 8
"	June 29	17	70,000	+ 7
F. R. Vaughn	August 26	14	7,000,000	+12
W. H. Haas	August 26	45	350,000	+10
"	1943 January 9	27	1,100,000	+12

of the earthshine, totalling less than 20, carried on by L. La Paz in 1938 with the 4-inch refractor of the Department of Astronomy of the Ohio State University.

Search for lunar meteors should be undertaken systematically when the end of the war permits uninterrupted observational work, for repeated observations of such meteors would go a long way toward proving the existence of a lunar atmosphere. In the table following are listed certain data relating to searches already made for lunar meteors. Negative results were secured in each of these searches.

My thanks are due to Dr. Lincoln La Paz of the Department of Mathematics of the Ohio State University for aid in the development of the ideas presented in this paper.

REFERENCES

[1] L. La Paz, *C.S.R.M.*, **2**, 35-40; *P. A.*, **46**, 277-82, 1938.

[2] See, *e.g.*, the discussion in T. W. Webb's "Celestial Objects for Common Telescopes," **1**, 6th Ed., 1917.

[3] W. H. Haas, *Jour. Roy. Astron. Soc. Canada*, **36**, 237-72, 312-28, 361-76, 397-408, 1942.

[4] C. Hoffmeister, "Die Meteore," 1937.

[5] C. P. Olivier, "Meteors," 1925.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Deep Minimum of V Hydrae: In 1926 attention was called for the first time to the fact that the N-type variable star V Hydrae, previously classified as an irregular variable, had a period approximating 530 days, but also, superimposed upon this period, was one of 6500 days, or about 18 years. Whereas the range in variation over the shorter term period was of the order of two to three magnitudes, the over-all, or maximal, amplitude amounted to six, from magnitude six to twelve.

Long period, deep minima were noted in 1889, 1907-08, and 1925. Now, in 1943, V Hydrae appears to have reached another deep minimum, at about magnitude twelve.

Of the numerous cases cited of variables with double or multiple periods, there appears to be none which closely follows the pattern of V Hydrae. Many M-type variables have been found to have multiple periods, but with small amplitudes, and usually they present alternately deep and shallow minima, at least for several cycles in succession. For the published light curve of V Hydrae from 1884 to 1926, see "The Story of Variable Stars," page 117.

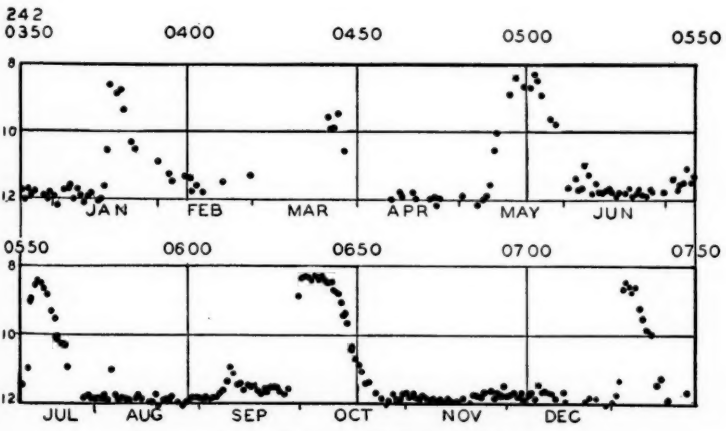
SS Cygni in 1942: In spite of the greatly reduced number of observations being contributed to the A.A.V.S.O. headquarters, the variable star SS Cygni was even better observed in 1942 than in 1941, a total of 816 observations having been made, and five maxima indicated, with apparently none missed.

The observations, under single day means, are listed in Table I.

TABLE I

DAILY MEANS OF SS CYGNI, 1942

243	—0—	—1—	—2—	—3—	—4—	—5—	—6—	—7—	—8—	—9—
0360	1 11.9	1 12.2	.....	2 11.75	1 11.7	1 11.6	2 12.00	1 11.7	1 11.9	1 12.1
0370	2 11.95	4 11.85	.....	2 12.05	1 12.0	4 11.65	2 10.55	5 8.62	.....	1 8.9
0380	2 8.80	4 9.40	.....	4 10.32	2 10.55	.....	.....	.....	.....	.....
0390	.....	1 10.9	.....	.....	3 11.27	1 11.5	.....	.....	.....	2 11.30
0400	1 11.4	1 11.8	1 11.6	.....	2 11.80	.....	.....	.....	.....	.....
0410	1 11.5	.....	.....	.....	.....	.....	.....	.....	1 11.3	.....
0440	.....	1 9.6	1 9.9	3 9.93	1 9.5	.....	1 10.6	.....	.....	.....
0460	1 12.0	.....	1 11.8	1 11.9	.....	.....	1 11.8	1 12.0	.....	.....
0470	.....	2 12.00	3 11.90	1 12.2	1 12.0	.....	.....	.....	.....	.....
0480	.....	1 11.9	.....	.....	.....	1 12.2	.....	1 12.0	1 11.9	1 11.6
0490	3 10.57	2 10.05	.....	.....	.....	1 8.9	.....	1 8.4	.....	1 8.7
0500	.....	1 8.7	1 8.3	1 8.5	2 8.95	.....	.....	3 9.63	1 9.8	.....
0510	.....	.....	1 11.7	.....	1 11.4	3 11.75	6 11.67	1 11.0	1 11.3	4 11.85
0520	4 11.58	1 11.8	1 11.8	1 11.7	1 11.7	1 11.8	3 11.93	1 11.8	.....	2 11.85
0530	1 11.7	2 11.90	3 11.83	1 11.7	4 11.85	1 11.9	1 11.7	1 11.8	.....	.....
0540	2 11.80	1 11.8	.....	2 11.40	3 11.77	1 11.6	2 11.50	5 11.12	5 11.52	5 11.36
0550	3 11.50	.....	3 11.03	4 9.02	7 8.59	6 8.42	7 8.56	5 8.68	6 8.82	7 9.37
0560	5 9.58	5 10.16	3 10.27	1 10.3	1 11.0	.....	.....	.....	.....	1 11.9
0570	1 11.8	7 11.90	1 11.9	7 11.91	3 11.93	3 11.80	11 11.95	7 11.03	2 11.80	4 11.98
0580	1 11.9	2 11.90	4 11.95	7 11.93	7 11.89	2 11.80	3 11.93	.....	10 12.00	4 12.00
0590	2 11.80	2 12.10	8 11.95	9 11.88	2 12.00	2 11.80	.....	7 12.00	2 12.10	2 12.00
0600	6 11.93	10 11.84	15 11.84	11 11.86	15 11.91	7 11.86	6 11.90	7 11.87	11 11.85	9 11.74
0610	5 11.66	2 11.40	2 10.95	5 11.16	4 11.52	6 11.45	10 11.63	13 11.47	3 11.57	3 11.53
0620	5 11.68	4 11.78	1 11.6	3 11.70	2 11.55	3 11.57	1 11.6	1 11.7	2 11.75	3 11.60
0630	2 11.70	5 11.18	5 8.90	8 8.35	5 8.28	9 8.31	8 8.40	8 8.29	3 8.40	5 8.28
0640	11 8.45	6 8.47	5 8.46	6 8.70	10 8.80	6 9.08	4 9.42	4 9.62	3 10.37	2 10.70
0650	3 10.93	8 11.09	3 11.47	3 11.40	.....	2 11.75	.....	3 11.90	1 12.1	2 11.95
0660	3 11.77	3 11.93	5 11.90	3 11.77	3 11.73	4 11.88	3 11.73	3 11.87	5 11.90	1 11.8
0670	4 11.82	3 11.93	5 11.90	2 12.00	2 11.90	3 12.00	5 11.90	1 12.0	2 12.05	4 12.02
0680	2 12.00	3 11.90	5 12.00	2 12.00	1 11.8	1 11.8	2 11.85	2 11.70	.....	4 11.68
0690	5 11.80	4 11.72	5 11.84	1 11.5	1 11.8	1 11.8	1 11.7	4 11.88	3 11.87	4 11.95
0700	3 11.80	4 11.78	5 11.92	2 11.45	1 11.7	1 11.7	2 11.75	3 11.77	1 11.9	.....
0710	1 11.7	1 12.0	.....	.....	.....	.....	.....	1 12.0	1 11.9	.....
0720	3 11.87	.....	1 11.9	1 12.1	.....	1 12.0	3 11.80	2 11.40	4 8.75	2 8.55



LIGHT CURVE OF SS CYGNI, 1942

Four of the five maxima were of the A-type. Maximum No. 326 was not sufficiently observed to determine its type. Table II contains the facts concerning the individual maxima. The maximum of October is number 329 of the series observed since 1896.

TABLE II

OBSERVED MAXIMA, 1942

No. Max.	Type	J.D. 10.0 I	Diff.	J.D. Max.	Diff.	J.D. 10.0 D	Diff.
325	A1	2430376	48	2430379	46	2430382	39
326	?	...	..	...	..	0444	62
327	A10	0490	..	0499	..	0508	64
328	A4	0552	62	0556	57	0560	52
329	A9	0631	79	0637	81	0647	87

The increase in light to magnitude eleven in September appears to be well established, as an examination of the values in the table will show.

Sources of Stellar Energy: In a paper presented to the American Philosophical Society in April, 1942, and just published in the *Proceedings* of that Society, Drs. C. P. and S. Gaposchkin discuss the possible sources of energy as deduced from a study of variable stars. It is not the intention to discuss here the whole problem as presented by the authors, but merely to point out the salient features of the paper.

The variables have been divided into three classes, Cepheids, long-periods, and semiregular red variables. For the different classes of variables we find tables which give relations between period, spectrum, effective temperature, luminosity, radius, and mass. Also there are tables for central condensation and polytropic index, and central temperatures of the stars. The final table gives masses and radii for eclipsing variables.

As has been known for some time past, a definite relation holds for all three classes of variables between spectrum, period, and absolute magnitude. For the Cepheids those of shortest period have the highest effective temperature, the lowest absolute magnitude, and the smallest radius and mass. For the long-period variables those of shortest period and earliest spectrum have the highest effective temperature, and, except for the K5e stars, the greatest absolute magnitude. The later Me-type stars of long-period have the greatest luminosity, radius, and mass.

For the semiregular variables, here again those of earliest spectrum have the shortest period, and except for the "giants" the highest effective temperature. The absolute visual magnitude for stars of spectrum M0 to M9 remains constant at 0.3, while the bolometric value increases from magnitude —1.2 to —4.5. For the c M-type stars the absolute visual magnitude is —5.2, while the absolute bolometric magnitude increases from —6.8 to —8.5 with increase in M-type. Also, radius and mass increase with period for the M0 to M9 semiregular red variables.

One important conclusion arrived at is that the central temperatures of almost all the intrinsic variables considered are less than ten million degrees, and those of the long-period and semiregular variables are less than three million degrees. Therefore the authors conclude that the carbon-cycle discussed by Bethe as the source of energy for stars of the main sequence can not be contemplated as the source of energy of the intrinsic variables. The alternative of the lithium-beryllium-boron process appears to be the most promising source.

The different types of variables seem to be associated with different sub-

atomic processes. No variable stars are seen to be associated with deuterium; lithium operates for the long-period and semiregular variables. The Cepheids span three subatomic processes, perhaps associated with the three groups that the progression in form of light curve has indicated.

This paper can well be considered as one of the most fundamental that has come out of the study of variable stars.

R Coronae Borealis Stars: Of the four R Coronae Borealis variables under current observation by the A.A.V.S.O., only one is now at normal maximum brightness. R Coronae Borealis itself is back again at the sixth magnitude after having decreased in light to magnitude 12.5 in November, 1942. As so frequently happens with stars of this type, the drop from six to below twelve was rapid, whereas the recovery to maximum light was slow and irregular.

SU Tauri, the first of the four stars to fade away, is still very faint after more than a year since it was last at maximum brightness. In September, 1942, the star started to increase in brightness again, but suddenly faded away in December.

RY Sagittarii, which began to fade away at about the same time as R Coronae Borealis—in September, 1942—is still below normal maximum brightness, apparently fluctuating greatly in light. Two definite minima have been noted, one late in November, 1942, and the other in March, 1943.

S Apodis, the last of the four stars to undergo a sudden diminution in light—late in December, 1942—was, according to the latest information from the South African observers, at magnitude 13.0 in March, 1943.

The A.A.V.S.O. at Cambridge: Although the A.A.V.S.O. did not hold an official business meeting this spring, a few members gathered at Cambridge in conjunction with the meetings of the American Astronomical Society held on May 28-29. The A.A.V.S.O. Council held a short meeting on Saturday noon—May 29—and transacted some necessary business. The approved council slate to be voted on in October includes the following names:

Marjorie Williams	Smith College, Northampton, Mass.
William L. Holt	Massachusetts State College, Amherst, Mass.
E. Dorrit Hoffleit	Harvard Observatory, Cambridge, Mass.
Lewis J. Boss	Warwick, R. I.

The following were duly elected to active membership.

Blakeney Saunders	Fort Worth, Texas.
J. L. Pouliot	Quebec, P. Q., Canada
Gordon Zeese	Great Neck, L. I., N. Y.
Thomas W. Stone	Richmond, Va.

E. Dorrit Hoffleit, having paid the usual life membership fee, becomes a life member of the association.

The Council voted to hold the next annual meeting at Harvard on October 8-9, 1943.

The Variable Star,— Telescopium, 1858*51:* Mr. A. W. J. Cousins of Durban, South Africa, again calls attention to the variability of a star in Telescopium—18 hours, 58.9 minutes, —51° 34′ (1900)—which he believes is of the eclipsing type, with a period of 777 days, or possibly half of that value. A definite minimum was observed by him on March 16, 1943, J.D. 2430800, and it appears to last for about 60 days. The period of 777 days satisfies the observations of Cousins, as well as those of Mr. Mark Howarth of Newcastle, N.S.W. The star appears

to vary between magnitudes seven and ten, and certainly requires still further attention, both visually and photographically.

Observations Received in May and June: We are certainly fortunate in having the continued cooperation of our observers in foreign countries, especially those in South Africa, Australia, and, when mail can get through, in India. More observations are now coming in from Argentina and Brazil. Canada, as well as Mexico, is also doing its share. Outstanding contributors for the past two months are Fernald, Wilton, Me.; de Kock, Cape Town, South Africa; Peltier, Delphos, Ohio; Nadeau, Quebec, Canada; Hartmann, St. Albans, N. Y.; Mrs. W. M. Kearons, Fall River, Mass.; A. S. Maupomé, Mexico City, Mexico; and the octogenarian, T. C. H. Bouton, St. Petersburg, Fla.

Observer	May —1943— June Var. Ests.		Vars. Ests.		Observer	May —1943— June Var. Ests.		Vars. Ests.	
Blunck	23	24	20	21	Manlin	49	49	19	19
Boone	9	9	12	12	Maupomé, A. S.	88	103	..	..
Bouton	48	68	42	48	Maupomé, E.	14	14	..	..
Buckstaff	7	16	22	40	Meek	37	150	..	..
Cousins	22	40	16	20	Moore	6	8	..	..
Dafter (Mrs.)	9	57	..	..	Nadeau	87	130	100	155
Duffie	14	14	16	20	Parker	36	41	54	54
Fernald	205	334	220	335	Parks	19	37	29	41
Garneau	12	19	19	21	Peltier	118	193	39	68
Hale	3	3	..	..	Rosebrugh	15	70	10	49
Harris	13	13	25	25	Sundage	6	22	14	25
Hartmann	88	102	49	49	Schoenke	18	25	34	68
Hiett	..	..	11	15	Segers	23	72	26	80
Holt	7	7	..	..	Sill	36	36	27	29
Howarth	15	17	18	25	Topham	12	12	4	4
Jones	24	48	24	43	Treadwell	5	5	..	..
Kearons (Mrs.)	89	145	54	108	Vohman	31	37	23	25
Kelly	11	14	11	13	Webb	15	16	11	12
de Kock	62	240	62	295	Weber	10	10	24	24
Koons	39	52	23	23					
Luft	10	86	10	84	(Totals)		2120		1851

July 15, 1943.

Comet Notes

By G. VAN BIESBROECK

There are no known comets visible in ordinary telescopes at this time. With powerful instruments two faint comets can be reached but both of them are fading and will not be followed much longer. They are COMET 1942 *g* discovered by F. Whipple last December 12 and COMET 1943 *a* found by Miss L. Oterma on April 8, 1943. It will be remembered that the first one became a naked-eye object visible all night in the spring when it traveled through the constellation of Ursa Major. Still visible in small telescopes in the beginning of June it dropped rapidly in brightness toward the end of that month. When last recorded here on June 30, the comet showed only a faint coma, most of the light being concentrated in a small nucleus not brighter than a thirteenth magnitude star. The visibility will probably come to an end in the latter part of July, the comet then being overtaken by daylight.

COMET 1943 *a* is much fainter than the previous one. Only a small number of measures have been obtained at the Flagstaff, Lick, and Yerkes Observatories.

Determining the orbit of this object has caused unusual difficulties on account of th great distance of this object. According to the unpublished computations of P. Herget the comet moves in a nearly circular orbit between Mars and Jupiter, the period being of the order of seven years. This accounts for the slow changes noticed in the brightness. It is quite possible that the comet might be located on prediscovery photographs provided that a sufficiently precise backward computation can be made from the short arc covered by the observations. This object, too, will be lost in the approaching light of the Sun before the end of this month.

In the morning sky PERIODIC COMET SCHWASSMAN-WACHMANN I can now again be reached. By means of the following ephemeris computed by Mr. Elemery of the Naval Observatory, I readily located the comet on June 29 when it appeared as a small round coma of magnitude 14. From previous experience we know that this comet has exhibited extreme changes in brightness in short intervals of time so it will be of interest to watch its behavior.

EPHEMERIS

1943	R.A. h m	Dec. ° ′
July 31	1 46.1	+20 5
Aug. 8	1 47.1	+20 26
16	1 47.5	+20 43
24	1 47.1	+20 56
Sept. 1	1 46.0	+21 5
9	1 44.3	+21 10
17	1 41.9	+21 10
25	1 39.0	+21 6
Oct. 3	1 35.7	+20 57
11	1 32.1	+20 44
Oct. 19	1 28.4	+20 28
27	1 24.7	+20 9
Nov. 4	1 21.2	+19 48
12	1 18.0	+19 26
20	1 15.3	+19 5
28	1 13.2	+18 45
Dec. 6	1 11.8	+18 27
14	1 11.0	+18 12
22	1 11.0	+18 1
30	1 11.7	+17 54

None of the periodic comets expected this year have been located so far. The search for COMET D'ARREST is being continued. Before long PERIODIC COMETS SCHAUMASSE AND DANIEL may be picked up in the morning sky, but both will probably be very faint.

Williams Bay, Wisconsin, July 12, 1943.

General Notes

Dr. Frank Schlesinger, formerly director of the Allegheny Observatory and of the Yale University Observatory, and well known for his many contributions to the development of astronomy, died on July 10 at the age of seventy-two years. A biography will appear in the following issue of this journal.

Dr. Frederick C. Leonard, Chairman of the Department of Astronomy of the University of California at Los Angeles, on May 26, 1943, addressed the student body of George Pepperdine College, Los Angeles, on the subject of "Copernicus and the Foundations of Modern Astronomy." The address was delivered in commemoration of the quadricentennial, on May 24, of the death of Copernicus and of the publication of his *De Revolutionibus.* Dr. Leonard was introduced by Mr. George Pepperdine, the founder of the College.

Miss Mary Hunt, formerly assistant in astronomy at Brown University, has recently joined the WAVES.

Private Thomas C. Varini, who was an enthusiastic member of both the Joliet Astronomical Society and the Joliet Mineralorists and contributed much by virtue of his energy and resourcefulness, was Joliet's first casualty in North Africa.

Celestial Navigation for Aviators

The above is the title of a book in preparation by Clarence H. True. He states that a new line of thought is presented which should appeal to the aerial navigator both for its simplicity and its practical application. Ordinarily a spherical triangle is solved by spherical trigonometry and logarithms. This new method eliminates the necessity of either. The zenith distance is found by rotating the Earth sphere, first about the polar axis, and second about the axis thru the observer's zenith. Actually a sphere is not used but only its projection on a plane surface which for convenience we will call the Earth Chart on which all problems are plotted. The zenith distance, altitude, and azimuth of the observed body, for the assumed position can be measured directly. Students in secondary schools as well as colleges, and all aviators regardless of schooling, can be taught the art of navigation by this method in a very short period of time.

Correction.—The photograph of the "Smoke Cloud from the Detonating Meteor of March 24, 1933" which appeared on page 210 of the April, 1943, issue of POPULAR ASTRONOMY with the caption, "Photo by Monnig," actually was taken by Mr. Bert D. Latham. This information was furnished by Mr. Monnig who obtained the picture from Mr. Latham.

Book Review

Astronomical Navigation Tables. (H.O. No. 218). Fourteen volumes. (Washington, D. C., 1941, 233 p. per volume, 14.2 x 24.6 cm.)*

These tables are restricted and are *not* for sale to the public. They are "reproduced by photo-lithographic process for emergency use from British Air Publication 1618." Each of the fourteen volumes covers five degrees of latitude; volume A, 0°—4°; —; volume P, 65°—69°. No volume bears the letter I or the letter O. The set is useful therefore only between 70° South and 70° North Latitude. Persons who have used these tables as well as other modern tables agree that they are the fastest tables available for navigational purposes at the present time. They are not as accurate as most other navigation tables; altitudes obtained from them are said to be correct to the nearest minute of arc, an accuracy entirely adequate for the aerial use for which they are intended.

In the front of each volume, about 89 pages are devoted to 22 bright navigation stars. Altitude and azimuth are tabulated to the nearest minute and the nearest degree, respectively, with arguments latitude (the five degrees covered by the volume) and hour angle (0° to 180° or down to 10° altitude) given to integral

*Essentially this same review appeared in *Mathematical Tables and Aids to Computation,* Vol. I, p. 82, July, 1943.

degrees. For each entry, a value is given (called t but *not* the local hour angle) which serves as an argument in entering the table on the inside of the front cover, to correct tabulated altitudes for any year to 2000 A.D. inclusive. No correction is needed in most cases before 1944.

In the latter part of each volume are tables in which for an integral value of declination (in degrees, 0° to 28° inclusive) altitude and azimuth are tabulated to the nearest minute and the nearest degree, respectviely, with arguments latitude (again for the five degrees covered by the volume) and local hour angle (0° to 180° or down to 10° altitude) given to integral degrees. For each entry, in the tables, a value of d is given, the change in altitude in minutes of arc corresponding to a change of one degree in declination; a multiplication table is given on the inside of the back cover and on the page facing it for purposes of interpolation.

This second half of each volume allows one to reduce observations of the Sun, Moon, planets, and 13 additional bright stars whose declinations are numerically less than 28° and for which data are available in the *Air Almanac*. In both sections of the volume, data for north latitudes are printed on one pair of pages, for south latitudes on the following pair of pages. At the top of each page is a clear indication in heavy, black type of the hemisphere to which the data apply.

One of the features which makes for speed in the use of these tables is that the tabulated altitudes are already corrected for refraction under normal conditions at an elevation of 5000 feet above sea level; thus an interpolated altitude is directly comparable with an altitude measured by bubble octant from a plane flying at 5000 feet. A small table of additional corrections due to refraction is given for elevations other than 5000 feet.

The bulk of the fourteen volumes, their weight and the fact that they are useful only between 70° North and 70° South are their chief disadvantages. The rapidity and simplicity of their use recommends them for the relatively crowded quarters of a plane under the perhaps unfavorable conditions of light, cold, low oxygen content of air, etc.

The excellent design of the tables indicates that experienced table-makers were consulted. This shows in the use of critical tables, the placing of the various tables, choice of type, and in other ways.

For purposes of comparison, the following table is offered:

	Volume (cc.)	Weight (lbs.)	No. nos. taken out	No. add. and sub.	Time req. (secs.)	Cost	Useful in latitudes	Min. alt.
H.O. 208	317	0.8	4	8	4	75	$ 1.20	90°N to 90°S	—90°
H.O. 211	216	0.5	7	9	5	90	$ 0.90	90°N to 90°S	—90°
H.O. 214	9752	15.	3	4	1	50	$18.00	80°N to 80°S	+ 5°
H.O. 218	11900	19.	3	4	1	40	....	70°N to 70°S	+10°

The number of entries is taken as the number of different pages which must be consulted—and this is increased by one if a volume has to be chosen from among several.

No great emphasis is to be placed on the estimates of time required for the use of the tables in the standard way; they represent only the times required by a few experts working under the most favorable conditions. The important fact is that none of the methods requires as much time as does the observation of a celestial body.

C. H. Smiley.

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